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ENGINEERING ANALYSIS

OF THE

RUSSIAN T34/85 TANK

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SEPTEMBER, 1951

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PREFACE

1. The engineering analysis of the Russian T34/85 tank forming the subject of this report is based almost entirely on an examination of one tank and one spare engine captured in Korea late in 1950 and forwarded

25X1A [redacted] in March, 1951.

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2. This analysis was confined to engineering appraisal, - to materials, manufacturing methods, and design. For more comprehensive information on the Russian T34 tank, reference may be made to the following reports by other Agencies:

   A. "U.S.S.R. Armored Vehicles and Anti-Tank Weapons" dated June 1948, produced by the Intelligence Division, G.S., U.S.A., Department of the Army.

   B. "Performance of Standard U.S.S.R. Tanks", Intelligence Review, Serial 156, Issue of March 1949.

   C. "U.S.S.R. Tank Development", Intelligence Review, Serial 106, dated March 1948.

   D. "Metallurgical Examination of Armor and Weld Joint Samples from Russian Medium Tank T34 and KV-1" No. W.A.L. 640/91, 24 Nov. 1943.

   E. "Russian Radio and Interphone Equipment Installed in Russian Medium Tank T34 and Russian Heavy Tank KV" Camp Cole Signal Laboratory, Red Bank, New Jersey C.C.S.L.. Engineering Report #6, 1943.

   F. "Second Partial and First Consolidated Report on Russian Medium Tank T34 and 10th Report on Ordnance Program #5887", dated 2 Dec. 1943, Army Ordnance Research Center.

3. In the course of this study, many comparisons have been made with information appearing in other reports. The following abbreviations have been used to facilitate reference to this other material:

Aberdeen Report	"Second Partial and First Consolidated Report on Russian Medium Tank T34 and 10th Report on Ordnance Program #5887", dated 2 Dec. 1943, Army Ordnance Research Center.

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German Report - "The Soviet Tank Diesel Motor", two articles appearing in the German magazine "Motortechnische Zeitschrift" for May and July, 1943.

Watertown Report - "Metallurgical Examination of Armor and Weld Joint Samples from Russian Medium Tank T34 and KV-1" No. W.A.L. 640/91, 24 No. 1943.

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4. [redacted] this investigation was identified as the G812 Program. The tank and engines were then identified as follows:

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G812 Tank — The Russian T34/85 tank sent [redacted] for this analysis.

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G812 Engines — The two T34 tank engines studied [redacted] one from the G812 tank, the other a spare engine received in addition to the tank.

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5. The main body of this report has been confined to information of general interest. The more highly specialized data and discussions have been segregated into a number of Appendices.

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[redacted] Duplicate negatives of these photographs can be provided in response to official requests directed to the Office of Collection and Dissemination, Central Intelligence Group.

Much additional information uncovered in the course of this study and consisting of some 200 detail photographs can be obtained from the C.I.A. Graphics Register. These photographs will be found especially valuable for use in comparing details of the vehicle here described with those of vehicles acquired in the future.

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OBJECT

This investigation of the Russian T34/85 Tank was undertaken for the following purposes:

1. To provide a general engineering appraisal of the vehicle in the light of American practice and design goals and in comparison with T34 tanks previously analyzed elsewhere.

2. To determine the condition of the tank as received, especially to uncover incipient failure of any components and thereby to estimate service life.

3. To appraise the materials used, - metals, rubbers, plastics, and others. To uncover evidence of adequacy of supply, and to judge the wisdom exhibited in materials selection.

4. To appraise manufacturing methods and equipment used for T34 production.

5. To note the extent of use of ball and roller bearings, items that were in critically short supply during World War II.

6. To study any engineering development revealed, and to evaluate the importance of this development.

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CONCLUSIONS

I General Engineering Appraisal

A. This investigation of the Russian T34/85 tank has provided a wealth of evidence to substantiate and explain the reputation for serviceability credited to this tank. This evidence falls under the following headings:

1. Virtually all parts were in operating order.

2. There had been a generous use of high alloy steels and other high quality materials.

3. Manufacturing methods had been adequate for the job, with crude exterior finish being countered by precision machining on functioning parts, according to need.

4. Ball and roller bearings were widely used, there being 88 in all.

5. Engineering development had been very actively continued; it was evident that most of the changes found through the comparison with the Aberdeen and German reports had probably been made to improve tank performance and especially tank service life, rather than to simplify or to reduce cost.

B. While no accurate estimate of the probable cost of this vehicle can be made from the information available, it is believed that the cost at the time of manufacture, converted to U.S.A. currency, would exceed $50,000.

C. The T34/85 tank examined was found to have many of the features regarded as important by American tank designers. This is brought out by the following tabulation of the major advantages and disadvantages of this tank, based on a comparison between the findings of this investigation and a set of specifications covering certain American tanks now in the course of design and development.

1. Desirable Features of the T34/85 Tank

(a) Materials were found ample for the job - better than those to be used in American tanks, in some instances.

(b) Accessibility for servicing was good, especially of engine components and storage batteries from the fighting compartment.

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(c) Plates containing operating instructions were conveniently located throughout the vehicle.

(d) Design was simple to the degree that the average mechanically trained crewman could attempt repairs with some assurance of success.

(e) Fire hazard was minimized through the use of a diesel engine rather than one requiring gasoline, and a major source of radio interference was eliminated.

(f) Ventilation of the crew compartment could be greatly augmented through the use of the engine cooling fan. This method could be used during gun firing to keep bore gas concentration in the fighting compartment at a minimum.

(g) A safety switch was provided in the gun firing circuit to prevent the gunner or commander from firing the gun until the loader signified his readiness by setting this switch. The switch was tripped by the gun during recoil.

(h) The engine crankcase breather tube was readily accessible from the fighting compartment, so that gasoline or other diluent could be added to the lubricating oil to insure the starting of the engine in extremely cold weather.

(i) The T34 is of lighter weight than the current U. S. medium tanks, but carries a gun only slightly smaller (85 mm vs. 90).

(j) Desirably low unit ground pressure of 10 lbs./sq.in. - our current design goal.

(k) Escape hatches were provided as considered desirable by U. S. designers.

one in hull over driver,
two in the turret,
one in the floor under the machine gunner.

(l) A machine gun was mounted coaxially with the tank gun, and another machine gun was mounted on the turret for use against anti-aircraft as well as ground targets.

(m) A pistol port was provided on each side of the turret.

(n) The turret could be rotated through 360° by power or by hand. Power traversing could be used for slewing, and

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a quick shift to hand traversing could be made for placing the sight and gun on target and for tracking a target. Turret position was indicated on an azimuth ring graduated from 0 to 60.

(o) The flat sloping armor in the front could be expected to provide desirable shell deflection properties.

(p) Armor thicknesses were approximately the same as those used in U. S. tanks.

(q) The cruising range could be expected to be 185 to 225 miles. This range was estimated by applying the Aberdeen finding of 150 to 187 miles for 120 gallons to the greater fuel tank capacity (147 gallons) found in the G812 tank.

(r) There was provision for both intercommunication and radio equipment; this equipment had probably been stripped from the tank in the field.

(s) Lifting hooks had been provided on both turret and hull, and there were towing hooks front and rear.

(t) An auxiliary starting means - the compressed air starting system - may have been more necessary because of the use of a diesel engine, but would be advantageous for gasoline engines as well, especially in very cold weather.

(u) The engine and transmission could be removed and re-installed with a fair degree of ease, since there were a minimum of lines and no electric wires to disconnect. The use of aluminum alloys for all castings of any size, except the cylinder head covers, eased the lifting problem. A smaller crane or hoist could be used than otherwise. Permanent lifting eyes were provided on both engine and transmission.

(v) Protective coatings seemed most effective. Very little rusting or other corrosion was found on functioning parts, despite the fact that the tank had been shipped from Korea without any weatherproofing, and had stood outdoors through several weeks of rainy weather before examination.

(w) Accessories not connected to the engine lubrication system were apparently expected to run for life on the initial lubrication given in manufacture. There was no provision for adding oil or grease to such accessories as the starter, generator, ventilating fan, and the traversing motor.

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2. Undesirable Features of the T34 Tank

(a) Rough steering due to the use of clutch and brake steering control, and

(b) Difficulty in shifting due to the use of a spur gear clash-shift transmission (no synchronizers, no clutches) and a multi-disc dry clutch, undoubtedly make driving this tank a difficult and very fatiguing job.

(c) Rough ride under some conditions, due to absence of shock absorbers, could contribute greatly to crew fatigue, as could

(d) Probably excessive noise resulting from the solid mounting of the engine in the hull (no rubber mountings) and the absence of mufflers. All-steel tracks contributed to this noise.

(e) Ground clearance was only 16" (Aberdeen figure). This was two inches below that considered necessary by the U. S. designers.

(f) Power traversing could not be used for putting the gun on target, but only for slewing. Hand traversing had to be used for the final positioning on a fixed target, or for tracking a moving target.

(g) All elevation was obtained by hand cranking. There was no provision for power assist.

(h) The liquid cooled engine and its attendant radiators made for greater vulnerability, due to loss of coolant because of concussion, small arms fire, or freezing.

(i) There was no basket platform in the turret. Greater risk of injury during slewing was imposed on the turret crew as the result.

(j) Fire protection was poor, consisting of two hand extinguishers containing pressurized carbon tetrachloride. The lingering poisonous vapor resulting from their use would be very likely to drive the crew out of the tank before it could be cleaned out by ventilation.

(k) There were many gaps at the joints in the armor that could have allowed entry of bullet splash and shell fragments.

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(l) There was no bore gas evacuator or other means of avoiding the discharge of bore gases into the fighting compartment when the breech was reopened. Note the item on ventilation, however, under "Desirable Features of the T34 Tank" above.

(m) The electrical system was only partially waterproofed. Except for the generator, starter, and starter relays, the electrical components could all be readily penetrated by water, with resulting acceleration of corrosion and deterioration of insulation.

(n) No auxiliary engine - generator unit was provided to keep the batteries charged or to supplement them, although only 100 ampere hour batteries were used. The generator on the propulsion engine probably did not exceed the 75 ampere charging rate appearing on the ammeter as a full scale reading.

(o) No provision was found for heating the oil as an aid to starting in extremely cold weather, although other measures had been taken, such as the provision of the compressed air starting system and of access to the crankcase breather tube for the adding of gasoline or other diluent.

(p) All the lubricating oil in the two oil reservoir tanks and all the coolant in the radiator cores, as well as in the engine had to be drained or be spilled into the hull when the engine was removed from the vehicle. No shut-off valves were provided, and no shut-off couplings. The connections to be opened were all rubber hoses held in place by screw clamps. Expanded beads had been provided at the steel tubing ends to keep the hoses from slipping off.

(q) The seals on rotating shafts throughout the vehicle were for the most part simply felt or fabric packing rings, generally without conical compressors, springs, or other means of insuring continued close contact with the shaft. The only lip-type seal found was in the fuel injection pump. There were no carbon seals.

(r) Wholly inadequate engine intake air cleaners could be expected to allow early engine failure due to dust intake and the resulting abrasive wear. Several hundred miles in very dusty operation would probably be accompanied by severe engine power loss.

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II Appraisal of Vehicle Condition

The tank and spare engine received for this investigation were both found in good condition. The tank appeared to require only track and charged batteries to put it in operation, though other equipment such as radio, intercommunication system, and machine guns had also been removed. The spare engine would have been ready to run after the flushing out of the vaseline-like grease used as a corrosion inhibitor.

Detailed examination revealed that most parts were in excellent condition, with no likelihood of early failure. The exceptions are listed in Appendix 15, "Failures". Most important among these were the transmission and final drive, - inadequate in design, and the front suspension members, - a manufacturing and inspection slip-up. Comment on the condition of individual parts has been included in the descriptive material accompanying the pictorial section of this report.

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III Materials Appraisal

Two facts clearly emerged from the materials study made on G812 tank components:

A. Ample supplies of high grade material, including alloy steel constituents that might have been critical, were made available to the tank manufacturing program at the time the G812 tank was built - late in 1945.

All materials analyses were made on the 1945 tank components, none of the 1948 engine parts being so tested. There was no evidence under visual inspection of the parts of the later engine that suggested any substitutions had been made. The later engine had even more aluminum, - in the three cast aluminum cooling fans added to the generator. Furthermore, the aluminum samples tested indicated virgin metal or the equivalent rather than secondary metal.

The materials provided for the tank program had been wisely used, not extravagantly. Alloying materials had been effectively used to obtain toughness along with the desired hardness. The armor, for example, was much harder than our specifications call for, yet at the same time tougher.

In general, the accompanying heat treatment seemed equally well suited to requirements, and control seemed quite satisfactory judging from the extensive hardness data obtained for this study. Departures from optimum materials treatment seemed likely to be the result of production imperfection rather than any lack of understanding. The inadequate drawing of the case-hardened transmission gears was an example.

Examination of rubber parts - natural and synthetic - again indicated a clear understanding of the special properties of the several types used. Heavy loading with fillers and resulting loss of physical properties - tensile strength and service life, especially, - suggested the possibility of shortage of synthetic rubber stocks, both of the neoprene and the buna types.

Plastics parts, the few that were found, were made of materials known in commercial practice for many years, materials that varied from poor to excellent in quality yet were regarded as adequate for the job in every application.

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IV Manufacturing Methods Appraisal

A. There was much evidence of comprehensive and detailed knowledge of modern manufacturing techniques. The following are indications:

1. Excellent castings, both steel and aluminum. Castings were generally found to be quite sound, free from blow holes and sand inclusions, and well filled out, though non-functioning surfaces were frequently found conspicuously rough.

2. Generally good heat treating, including nitriding and carburizing as well as through-hardening. Maximum surface hardness had been reached in many of the carburized parts, e.g., 67 Rockwell C on the oil pump idler gear.

3. Use of several types of welding technique, both manual and machine, including the submerged arc process.

4. Skillful handling of the plates used in the multiple plate clutches, to result in their staying flat in service. Cross rolling of the stock and careful grinding are required to prevent warping when the clutch is heated during slipping.

5. High grade finishes and close tolerances held on such parts as the fuel injection pump plungers and barrels and the rack and pinions. The injection nozzles and the air starter distributor also offered such examples.

6. High quality engine valve springs, free from seams and die marks and otherwise smooth-surfaced, and zinc plated despite the risk of hydrogen embrittlement.

7. Ground worms with smooth, chatter-free finish were found in the turret traversing and gun elevating mechanisms.

B. Knowledge and understanding of manufacturing methods were sometimes not matched by execution in actual production. For example,

1. The aluminum castings were generally very good. The sand castings, however, suffered from unskilled molding technique, from soft ramming, inferior mixes, and rough handling of cores. There were many instances of core wire and sand inclusions. The permanent mold castings were admirably clean, free of blow holes, and well filled out. However, improper closing of the molds had resulted in heavy parting lines and flash, requiring much extra cleanup work, a hand job (snagging) that was crudely done.

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2. Heat treatment, found very effectively controlled in most parts tested, was imperfectly controlled in the all-important transmission gears where insufficient drawing of the case had resulted in excessive surface cracking under load. This contributed to transmission failure, though perhaps of secondary importance. The lower sloping front armor plate on the hull had been poorly quenched or tempered, the temperature having been too low. The upper plate was found properly treated.

3. Knowledge of various welding techniques was not matched by welding skill; many cracks were found in and under the hull welds, some seriously weakening the joint. Most of the manual welds were very rough and irregular in appearance, adding to the impression of a low order of skill.

4. Lack of skill in flame cutting had apparently been the reason for the grinding of the corners of the driver's hatch opening.

C. Manufacturing equipment was being run at capacity or overloaded, judging from the plentiful evidence of extremely course feeds, severe chatter, and tearing and rubbing of machined surfaces. Inadequate machine maintenance and the running of tools much beyond the optimum point for resharpening could have contributed materially. It should be emphasized again, however, that low grade machining was essentially confined to stock removal, to the provision of clearance space. Mating surfaces were machined with much greater care, though even this machining was frequently compared unfavorably with American workmanship.

D. Examination of the G812 tank parts suggests the following picture of manufacturing equipment committed in 1945 to the T34/85 tank program:

1. The largest casting required of the foundry facilities was the turret, weighing about 9,000 pounds. Problems of casting technique and equipment had been simplified by the building up of the hull from a number of cast and rolled components. Even the turret roof was found to be a separate piece welded on.

2. Demands on armor plate rolling equipment had also been eased by the built-up hull construction. No bent plates were used, nor had the plates been taper-rolled.

3. Considerable use was made of closed die forgings. The crankshaft and the four camshafts were so formed, the former requiring at least a 25,000 pound hammer.

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4. Stampings and drawn parts were more widely used in the G812 tank than in the T34 on which the Aberdeen Report had been based. The fuel tanks were among the largest parts so made, being built by welding two drawn halves together rather than by welding up flat stock as was formerly done.

5. Molded and laminated plastics parts found on this tank could have been made with the simplest and crudest equipment. The generator and fuel injection pump coupling discs, the valve knobs, and the molded battery cases are examples.

6. There was no evidence of any unusual machining equipment being required. The heavier machining could all have been done with conventional horizontal lathes and mills, vertical lathes and mills, drill presses, and other pieces of standard equipment. Machine tools used in railroad equipment manufacture could well have been applied to the job. There was no definite indication of gang machining; it was difficult to say whether the many flange holes in the transmission case were drilled successively or simultaneously. It was clear, however, that extensive use had been made of drill jigs.

7. Shapers and hobbing equipment had been used for the machining of most of the gears. The spiral bevel gears used at the input of the transmission had required a special gear generating machine. The worms used in the turret traversing and gun elevating mechanisms had required a thread grinder and probably also a thread mill.

E. There was much evidence of hand work:

Hand polishing of the connecting rods.

Hand finishing of the cam noses on the four camshafts in each engine.

Hand grinding at the driver's hatch to dress up rough flame cutting.

Extensive hand snagging of aluminum castings to make up for poor mold closure and the resulting heavy seams.

Breaking of edges on many machined parts.

Hand welding of the fuel tanks, suggesting the lack of seam welding equipment.

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Blacksmith forming of most of the special purpose tools found in the vehicle. A small American-made end wrench was one of the few exceptions.

Hand hammering and bending of small sheet metal parts - the hollow chamber found in the engine cooling system, for example, and the radiator top tanks.

F. [redacted]

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Yet a failure to machine sufficient clearance at the clevis root of the front suspension spring arms had not been caught by inspection. As the result, both front suspension spring guide rods had been bent and had worn severely. The sticking of these bent rods in their bushings could have caused loss of track tension and consequently loss of track. It is not known whether the track had actually been lost before the tank was captured.

No cooling tests were run on the G812 tank, but earlier data had indicated insufficient radiator cooling capacity. It was therefore of particular interest to note that the exceptionally poor soldering job that had been done on the radiator core fins and tubes on the G812 tank had not been rejected by inspection (or that these radiators had been used despite rejection). As the result of this poor soldering, the fin-to-tube contact was probably less than 10% of that obtainable. By the most conservative estimate, the G812 radiators had much less than 50% of the capacity that could have been reached through the correction of just this one manufacturing operation.

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V Ball and Roller Bearings

Of the 88 ball and roller bearings found in the G812 tank, only six could be positively identified as of other than Russian make. These were the six American-made bearings, identified [redacted] as having been manufactured during the World War II Lend-Lease period. 25X1B

Ball bearings comprised 54 of the total, the other 34 being roller bearings including needle bearings. All bearings are listed in Appendix 6, being described by application or location and by size. Also included is a breakdown by types - thrust, self-aligning, etc.

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Eight of the roller bearings were tested for geometry and finish as well as material, and one of these was given a controlled life test. This work was done by [redacted] Their report, included as Appendix 7, indicates that the bearing under life test failed after only 14 hours under conditions expected to produce few failures at 300 hours in comparable [redacted] bearings. The eight had been found to conform to American practice so far as metallurgy, surface finish, and geometry were concerned. It was surmised that residual stresses may have been responsible for the premature failure.

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VI Evaluation of Engineering Changes

A. The 37 items listed under "Design Changes", Appendix 17, suggest active continuation of engineering development of the T34 tank in the two to three years between the manufacture of the T34/85 tank examined in this study and the T34/76 studied for the Aberdeen Report, aside from the obvious change in armament. The G812 engines were both provided with many improvements over the engines described in the Aberdeen and German Reports.

B. Most of this continued development seemed directed toward product improvement, especially toward increase in the tank's service life. The following are illustrative:

1. Cast steel bogie wheels with solid tires, rather than drawn steel wheels with perforated tires.

2. 3" turret wall thickness, rather than 2".

3. Higher capacity generator.

4. Improved generator drive coupling.

5. Improved water pump drive coupling.

6. Lighter water pump impeller.

7. Better lubrication of the water pump bearing.

8. Fuel tank capacity increase of 23%.

9. Better fuel tanks - less welding.

10. Greater air cleaner capacity. However, the higher dirt removal efficiency intended was probably not achieved.

11. Better lubrication of the engine accessory drive.

12. A large filter, rather than merely an oil strainer, for the lubricating oil.

Among the changes listed above were corrective measures for virtually all the T34 defects revealed in the course of the tests run at Aberdeen in 1943 (see the Aberdeen Report). The only important defects not so recognized were the lack of shock absorbers - the G812 tank had no shock absorbers - and the transmission deficiencies.

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C. Not all of the changes made were successful. It is very doubtful that any improvement in air cleaning efficiency was obtained when the old air cleaner over the engine intake manifolds was replaced with the two tractor-type cleaners. The latter had the same general appearance as American tank air cleaners but could be expected to have very inferior efficiency. Centrifugal separation of dirt from air was abandoned several decades ago in America as being very ineffective in motor vehicle application.

With this serious defect combined with the low cooling efficiency due to poor radiator soldering, this tank would have made a very poor showing in operation in hot dusty country.

D. Changes included some for the convenience of the crew. An over-center spring for the main clutch reduced the foot pedal pressure required to disengage it. Better arrangement of the engine instrument panel made it easier to reach controls without error and to read the meters. Bringing the two starter controls together facilitated using the air starter to supplement the electric starter and to use it only as long as was needed. New instruction plates were offered for crew guidance and were very brief and to the point.

E. As noted under "Design Changes", there were a few differences between the two G812 engines, including the improvement in the lubrication of the lower accessory drive. That the older engine found in the tank was as nearly like the service replacement engine suggests the possibility that the older engine had been rebuilt to bring it more nearly up to date.

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DETAILED DESCRIPTION

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G812 RUSSIAN T34/85 TANK

"As Received" Condition:

- No track.
- No intercommunication system or radio, although loose wires that may have been used for such systems were found.
- Sheet metal bent and tires gouged by rough handling.
- Outside equipment included:
  3 auxillary tanks for lubricating oil or fuel.
  5 track sections,
  2 tool boxes on running boards.
- No machine guns.
- No lights or horn.
- No periscopes.
- No gun sights.

Identifying Details:

- Radio antenna on turret, instead of hull, as on Aberdeen tank.
- Cast steel bogie wheels with solid tires. Aberdeen tank had drawn steel wheels and perforated tires.
- Sharp edged front (Aberdeen was round nosed.)
- Spare track sections in front (on side on Aberdeen tank).
- Spare tanks on sides, provision for mounting similar tanks on rear and for dropping rear tanks from within the vehicle.
- Cast turret except for welded top carried 85 mm gun.
- Hatch over the commander had 3/4 opening lid on ball race, apparently to serve as machine gun mount.
- Extra handles, and towing hooks, front and rear, with retaining members.

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0010 - T34 RUSSIAN TANK - LEFT SIDE

1. Bogie wheels
2. Track idler wheel
3. 85 mm gun
4. Track drive whee.

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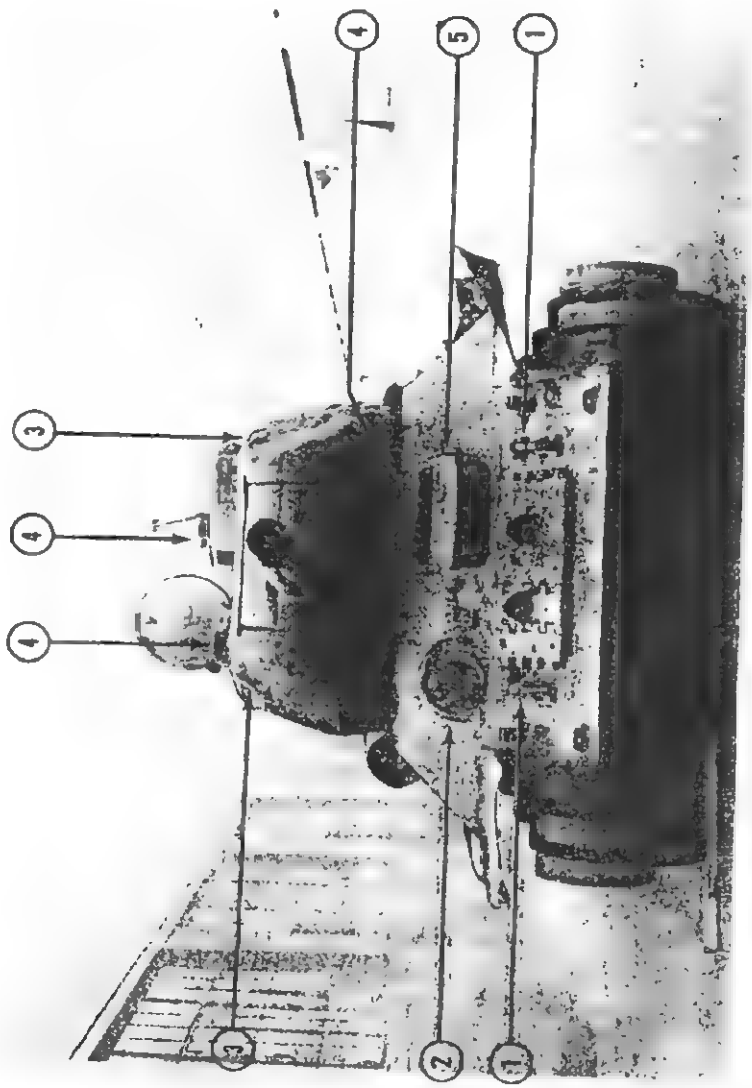

0010.1 - T34 RUSSIAN TANK - FRONT VIEW

1. Towing and lifting hooks
2. Machine gun mount
3. Turret lifting hooks
4. Periscope mounts
5. Driver's hatch

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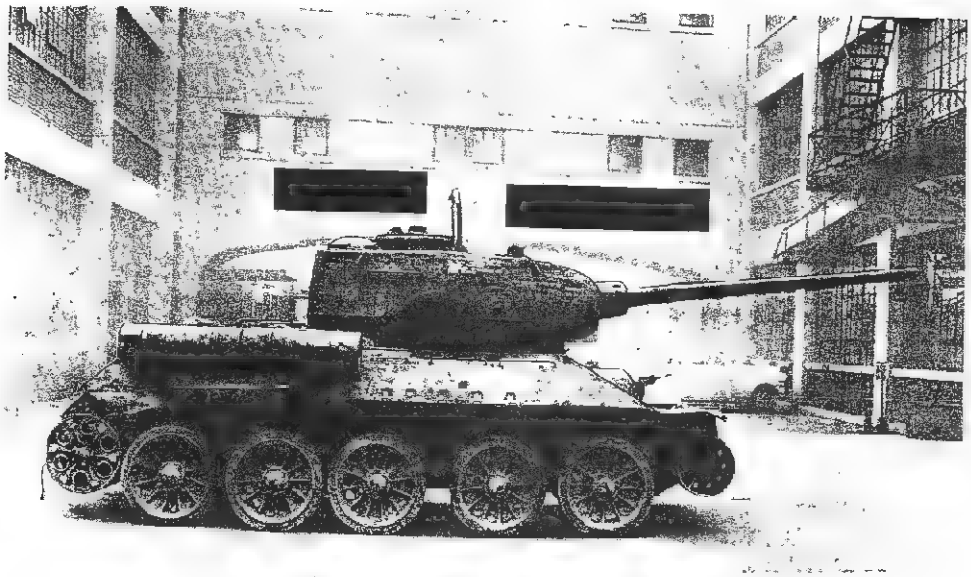

0010.2 - T34 RUSSIAN TANK - RIGHT SIDE

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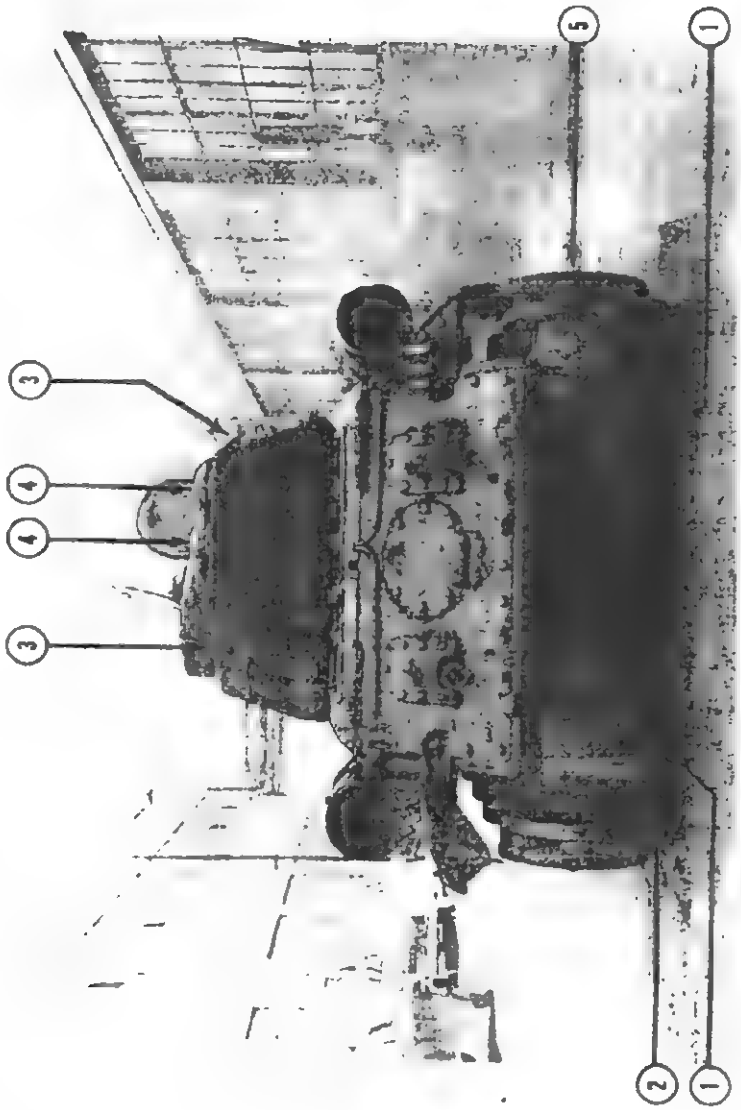

3010.3 - T34 RUSSIAN TANK - REAR VIEW

1. Towing arc lifting hooks
2. Final drive housing
3. Turret lifting hooks
4. Turret Ventilators
5. Track drive wheels

C02923529

ENGINE

V12 Diesel, a conversion of the Hispano-Suiza aircraft engine.

Size — 2370 Cubic inches displacement
150 mm bore (5.9 inches)
180 mm stroke (7.1 inches)

Rating — 500 Brake horsepower at 1800 rpm
1665 pound feet brake torque at 1200 rpm

Weight — 2000 pounds, without fan, clutch, transmission, or fluids.

Materials — All large castings are aluminum alloy, excepting only the cylinder head covers. All major working parts are nickel-chrome alloy steel, most of them Krupp steel.

Workmanship — Not in every case as good as that on American tank engines, but apparently adequate for the purpose.

Accessory Equipment — German type fuel injection pump - 12 plunger assemblies in line.

24 volt electric starter with over-running clutch drive.

Air starter system in addition, with two storage cylinders charged at approximately 1000 psi providing the source of energy.

Electric generator to help carry the electrical load and to charge the storage batteries. Estimated capacity: 75 amperes. (No auxiliary generator plant was provided in the T34, however).

Fuel oil filter, with thick felt element.

Lubricating oil filter, with three edge-type concentric cylindrical elements connected in parallel, and with an over-pressure bypass valve.

Centrifugal water pump with a pressurized grease reservoir for continuous lubrication of the pump bearing.

Lubricating oil pump, actually three pumps in tandem, with one pump serving as pressure source for the engine, and the two other pumps serving as scavenge pumps to transfer oil from the engine crankcase to the oil cooler and the two oil storage tanks.

Fuel oil pump, vane type, constant displacement, with relief valve, to transfer fuel from the fuel tanks to the injection pump and to maintain a constant pressure on the latter.

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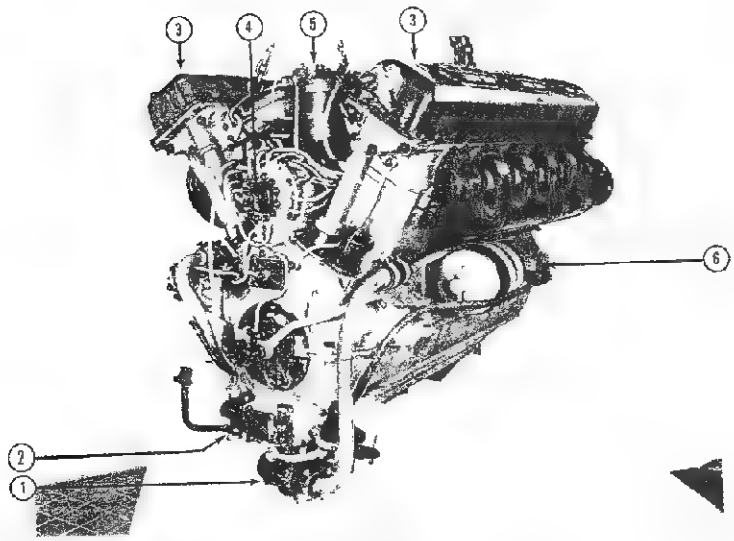

0100 a - ENGINE [redacted] - FRONT RIGHT VIEW 25X1B

1. Water pump
2. Fuel transfer pump
3. Head cover
4. Air starter distributor
5. Fuel filter
6. Lubricating Oil Filter

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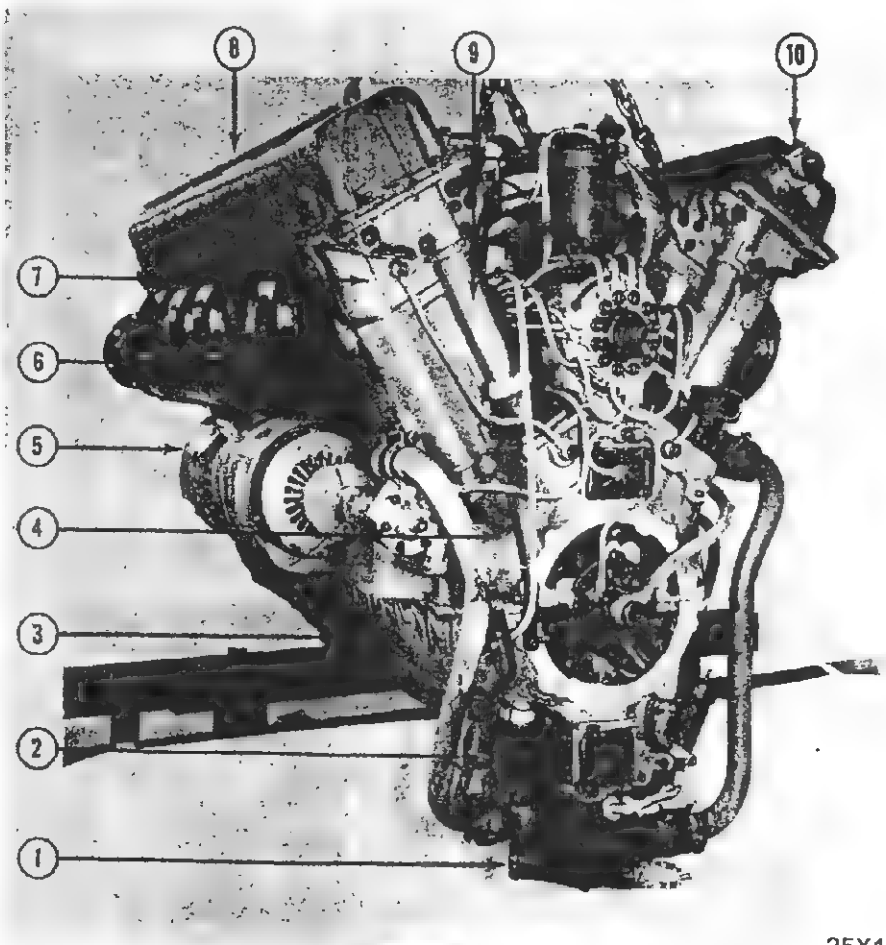

25X1B

0100 c - ENGINE [redacted] - FRONT LEFT VIEW

1. Water pump
2. Fuel transfer pump
3. Lower crankcase
4. Upper crankcase
5. Generator
6. Cylinder block
7. Cylinder head
8. Cylinder head cover
9. Camshaft drive shaft housing
10. Tachometer drive

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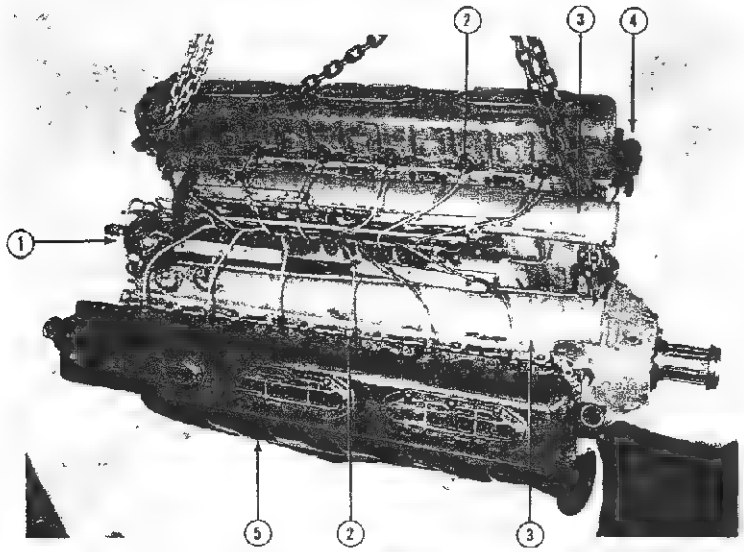

0100 f - ENGINE [redacted] TOP VIEW 25X1B

1. Fuel filter
2. Fuel injector connections
3. Intake manifolds
4. Water connections
5. Exhaust manifold

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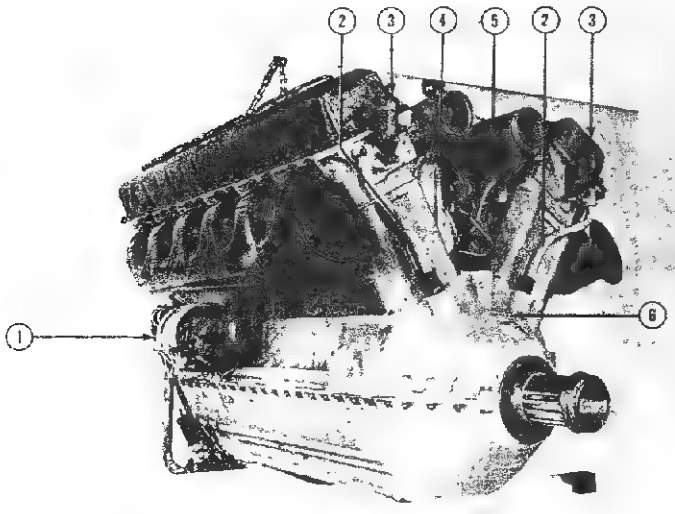

25X1B

0100 g - ENGINE [redacted] REAR RIGHT VIEW

1. Oil filter
2. Oil return front heads to crankcase
3. Water line connections
4. Governor
5. Air starter system connections
6. [redacted]

25X1B
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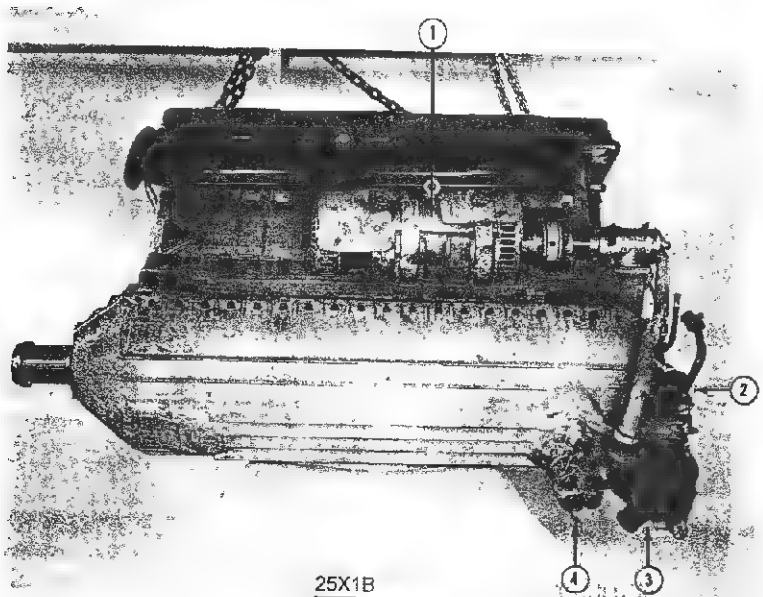

25X1B

0100 1 - ENGINE [redacted] RIGHT BOTTOM VIEW

1. Generator
2. Fuel transfer pump
3. Water pump
4. Lubricating oil pump

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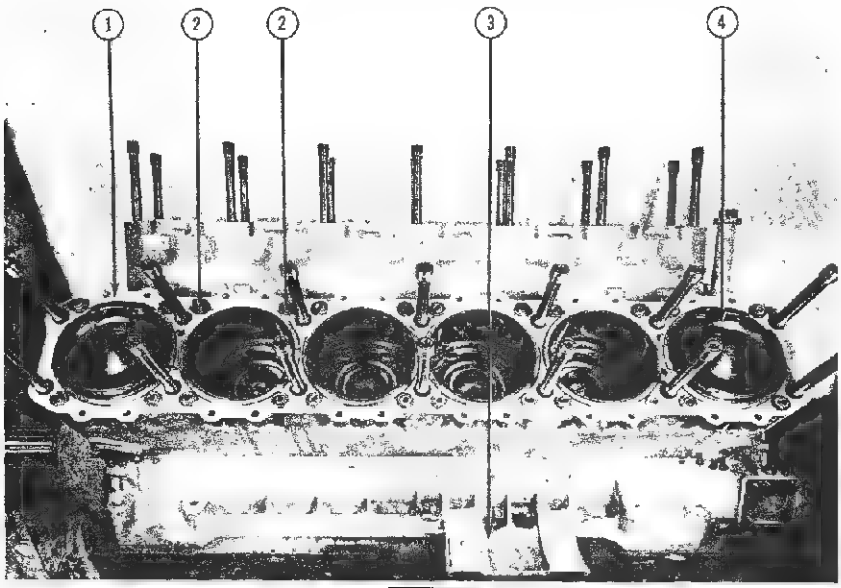

100 q - ENGINE [redacted] LEFT VIEW 25X1B

1. Aluminum head gasket
2. Water ports with rubber gaskets
3. Generator bracket
4. Piston

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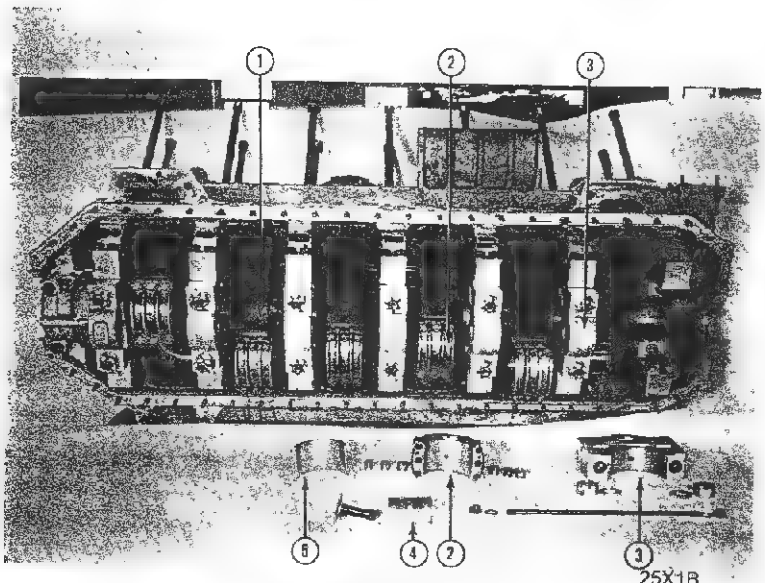

0100 s - ENGINE [redacted] BOTTOM VIEW

1. Connecting rod assembly
2. Main connecting rod bearing cap
3. Main bearing cap
4. Auxiliary connecting rod pin
5. Main connecting rod bearing insert

[redacted]

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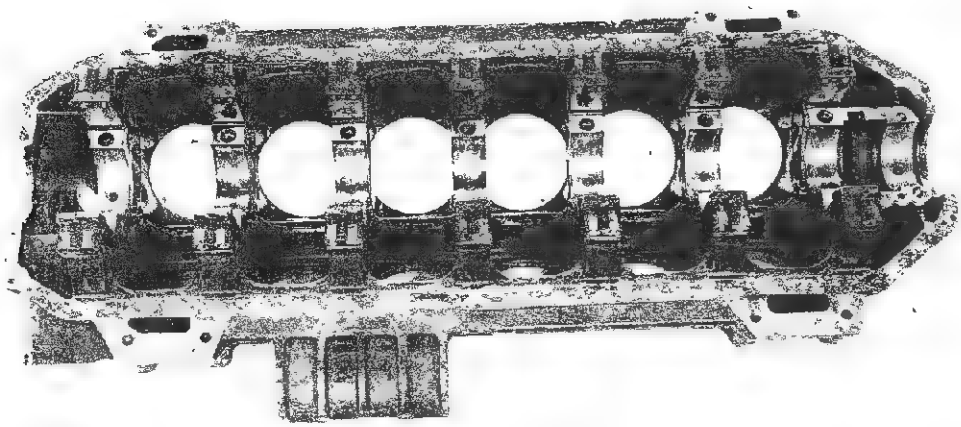

25X1B

0101 b - UPPER CRANKCASE - ENGINE [redacted]

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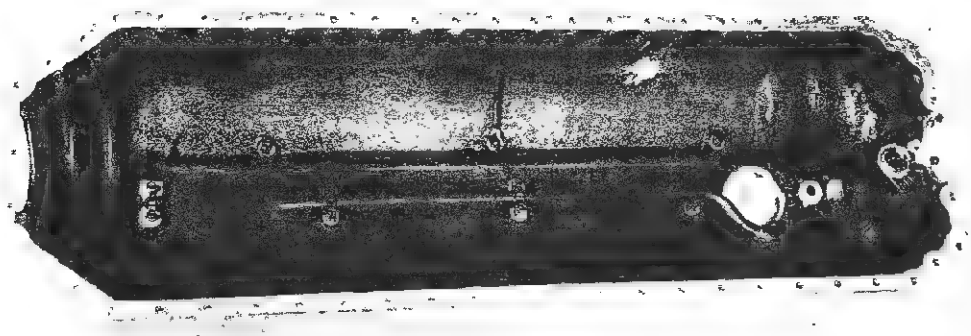

25X1B

0101.0.1 - LOWER CRANKCASE, INSIDE VIEW - ENGINE [redacted]

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ENGINE - CYLINDER BLOCK

The steel wet liner sleeves are provided with a top shoulder that fits directly against the aluminum casting counterbore and is held in close contact by pressure from the cylinder head. The liner sleeves are sealed at the lower end by rubber rings. Natural rubber is used to make the water seal rings and a neoprene-type synthetic rubber is used for the oil seal rings. These rings are slid between the liner and the cylinder block until they come to a stop against a shoulder on the liner and are compressed into this space when the block is bolted to the upper crankcase.

Note the triangular pads near the bottom of the cylinder block at each end. The pad shown at the right of the photograph was used to provide connection for water from the water pump. The pad at the left was simply covered and served no purpose on this engine. It appeared as though the block was made symetrical in this respect to be used as either a right-hand or a left-hand block. It seems surprising, however, that all machining was completed so that studs and a cover plate had to be provided.

The cylinder block is made of a silicon-aluminum alloy. The permanent mold, sand core method of casting is used. The cylinder liners are made of a nitralloy steel and are nitrided on the inside and zinc plated on the water side.

25X1B

Four cylinder liners removed from engine [redacted] were gauged for uniformity of bore. Excellence of machining and freedom from wear are indicated by these measurements. The measurements are contained in the accompanying table. This table reveals only small variation due to taper and out-of-roundness in the liners checked. Taper of the top three inches, a possible measure of wear such as might have been accelerated by dust passing through the air cleaners, was very slight. None of the liners showed any appreciable scoring or other local wear. If the 741 km shown on the vehicle odometer was correct, it would be likely that very little dusty operation of the engine occurred.

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CYLINDER LINER BORE DIAMETERS

Distance from Top of Liner	Sample #1		Sample #2		Sample #3		Sample #4	
	Max. ID	Min. ID	Max. ID	Min. ID	Max. ID	Min. ID	Max. ID	Min. ID
3/16	5.9089	5.9074	5.9071	5.9064	5.9088	5.9084	5.9082	5.9082
5/16	5.9094	5.9095	5.9085	5.9084	5.9098	5.9094	5.9101	5.9103
1	5.9095	5.9079	5.9069	5.9064	5.9079	5.9071	5.9073	5.9070
1-1/2	5.9093	5.9080	5.9070	5.9059	5.9078	5.9069	5.9072	5.9068
2	5.9096	5.9082	5.9071	5.9057	5.9077	5.9069	5.9075	5.9067
3	5.9095	5.9084	5.9070	5.9056	5.9078	5.9068	5.9076	5.9069
4	5.9097	5.9087	5.9071	5.9056	5.9078	5.9068	5.9076	5.9068
5	5.9095	5.9087	5.9073	5.9054	5.9079	5.9069	5.9076	5.9069
6	5.9094	5.9088	5.9078	5.9066	5.9082	5.9071	5.9078	5.9069
7	5.9095	5.9089	5.9088	5.9064	5.9086	5.9075	5.9078	5.9069
8	5.9095	5.9084	5.9091	5.9071	5.9091	5.9077	5.9078	5.9070
9	5.9084	5.9082	5.9086	5.9062	5.9082	5.9068	5.9066	5.9061
10	5.9082	5.9077	5.9076	5.9056	5.9080	5.9066	5.9066	5.9056

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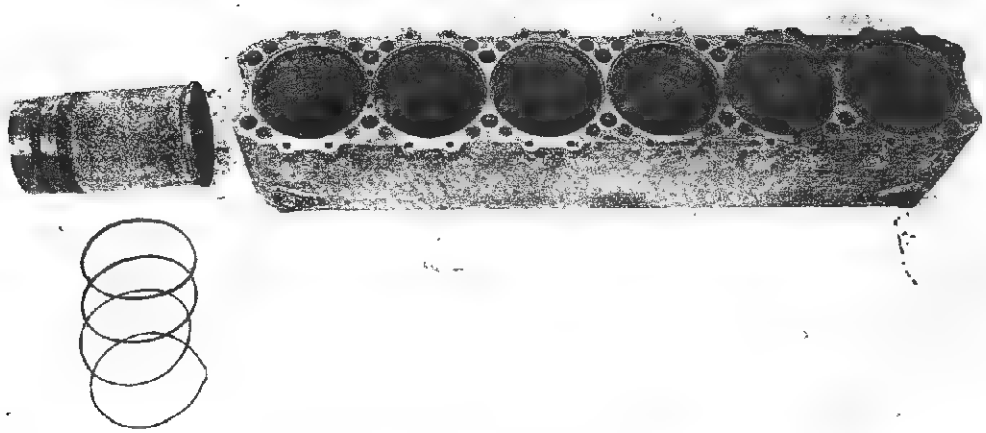

0101.1 c - CYLINDER BLOCK, TOP VIEW - ENGINE 25X1B [redacted]

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ENGINE - CYLINDER HEAD

The cylinder heads fasten to the cylinder blocks by 14 studs of 18 mm diameter, which go through the blocks into the upper crankcase, and 24 smaller studs, which screw into the head and are secured by nuts under a shoulder on the block.

An aluminum gasket provides the seal between the head and the cylinder liners. Concentric grooves are machined into the face of the head around each combustion space and into the shoulder of the liners, to provide a more positive seal with the gasket. The aluminum gasket provides no water passage seal between the head and block. This sealing is done by rubber grommets located by clearance holes in the aluminum gasket. These grommets are provided with tubular brass cores that serve to prevent the reduction of water passage area when the grommets are crushed between the head and block.

The combustion space in the head has been machined. Four openings are provided in each combustion space for inlet and exhaust ports. The openings (the intake and exhaust ports into the combustion space) are machined to receive steel valve seat inserts, which are pressed in against the shoulders provided. The valve guide bushings are also steel. (See photograph 0101.2k. The German report mentions bronze valve seat inserts and guides. Two more openings into the combustion space are provided. One is for the fuel injection nozzle and is located in the top center of the combustion space. The other opening is located on the intake side of the combustion space and is to introduce the compressed air used for starting the engine.

The head is made of an aluminum-silicon casting. The permanent mold with sand core process was used. The sand cores were necessary to form the intake and exhaust ports and the water jacketing. The clean-out holes for removal of the sand cores had been machined and threaded to receive brass plugs. A fibrous cord was wrapped around each plug just under the shoulder, presumably to aid in sealing.

The heads were designed so that the same mold could be used for casting either of them. Machining differences made them no longer interchangeable.

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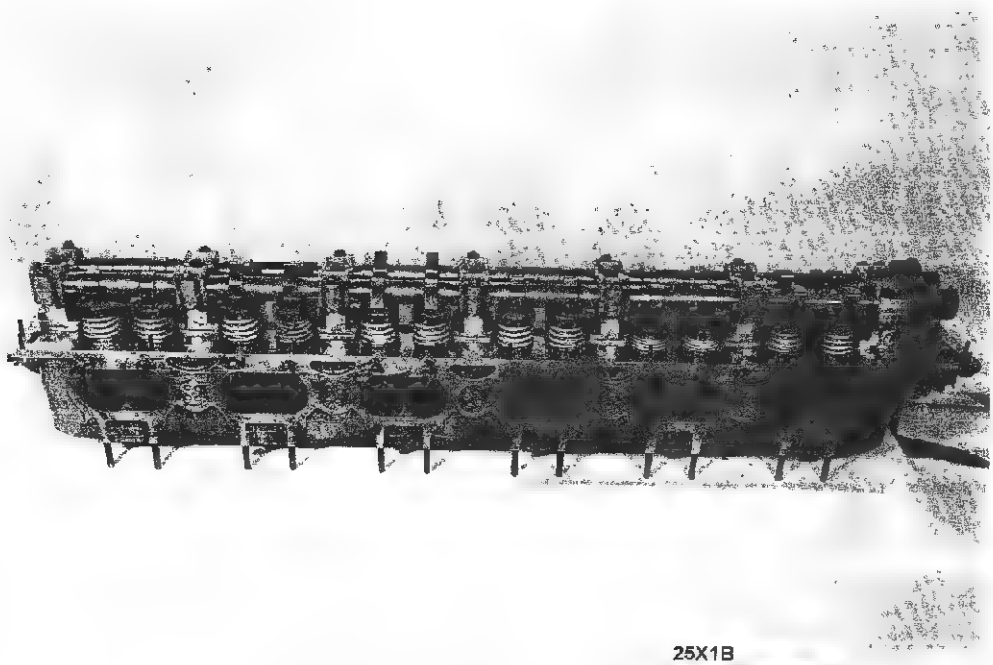

6101.2 a - LEFT CYLINDER HEAD - ENGINE 25X1B [redacted]

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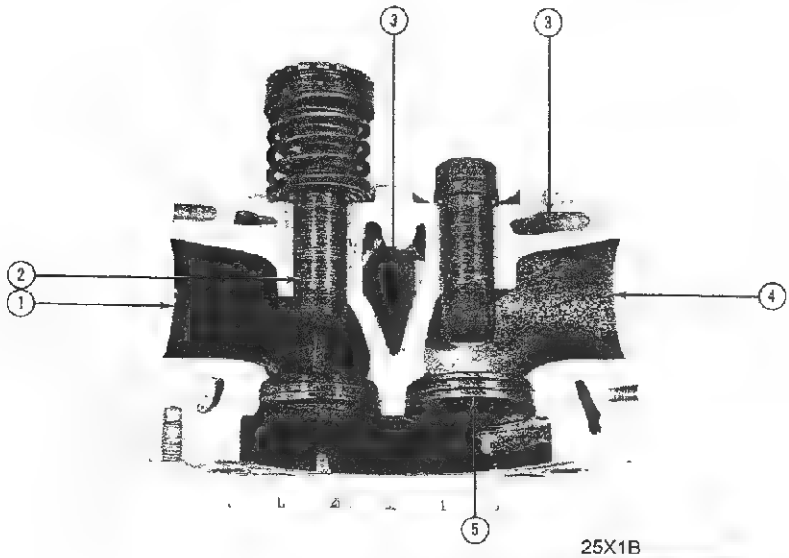

25X1B

0101.2 k - CYLINDER HEAD SECTION - ENGINE [redacted]

1. Exhaust port
2. Valve guide
3. Water jacket ports
4. Intake port
5. Valve seat

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25X1B

ENGINE - CYLINDER HEAD COVERS

Three different designs of cylinder head covers were found on the two G812 engines. All were cast iron in contrast to the aluminum castings used for other major engine parts. The covers on engine [redacted] had no access plates for servicing of injector nozzles. The entire head cover had to be removed to do any servicing of the injector nozzles.

25X1B

Both covers on engine [redacted] had removable access plates. On one of these covers, the plates were steel stampings and on the other they were cast iron. It is probable that the head with steel plates is a replacement, since the other head was finished to match other iron castings on the engine.

Head covers were cast to be used on either engine bank, but machining differences made the head covers no longer interchangeable.

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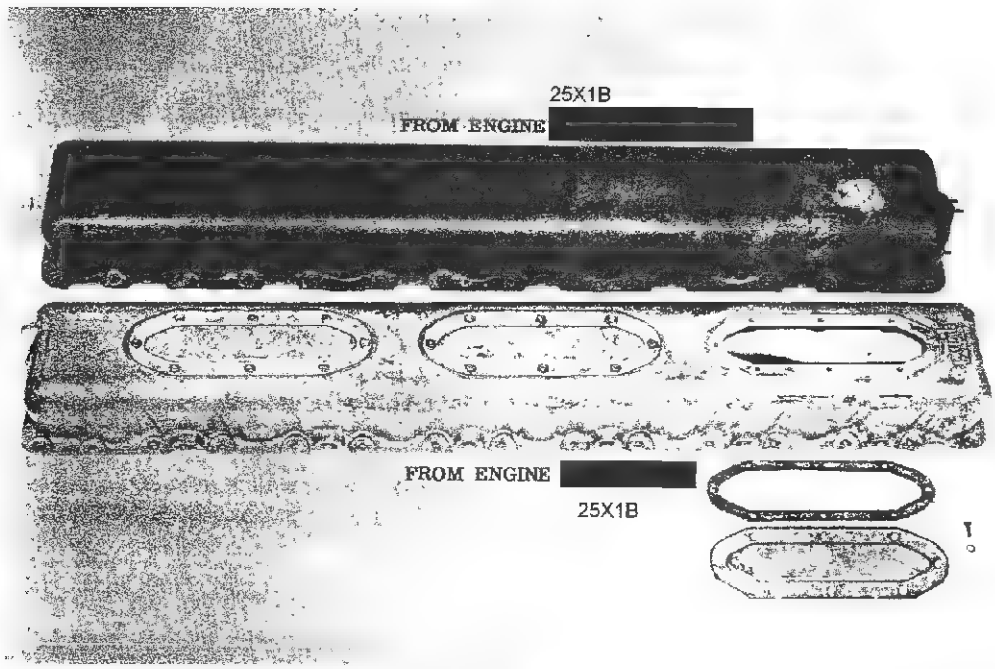

0101.3 - CYLINDER HEAD COVERS

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25X1B

CRANKSHAFT [redacted] ENGINE

This crankshaft, machined all over, was found to have been forged rather than turned from a billet. Note the provision of the ball thrust bearing between the two rear main bearings. No difference was found between the two crankshafts from the two engines examined.

25X1B

CRANKSHAFT THRUST BEARING - [redacted] ENGINE

This precision ball bearing had the following dimensions:

ID	100 mm
OD	135 mm
Width	25 mm

The axial play of this bearing and retainer assembly would be determined by the tolerances on five pieces, yet the play was judged to be less than .002, even though no shims were used.

A corresponding ring groove in the crankcase and in the bearing cap provided approximately the same precision of location for the bearing at these points.

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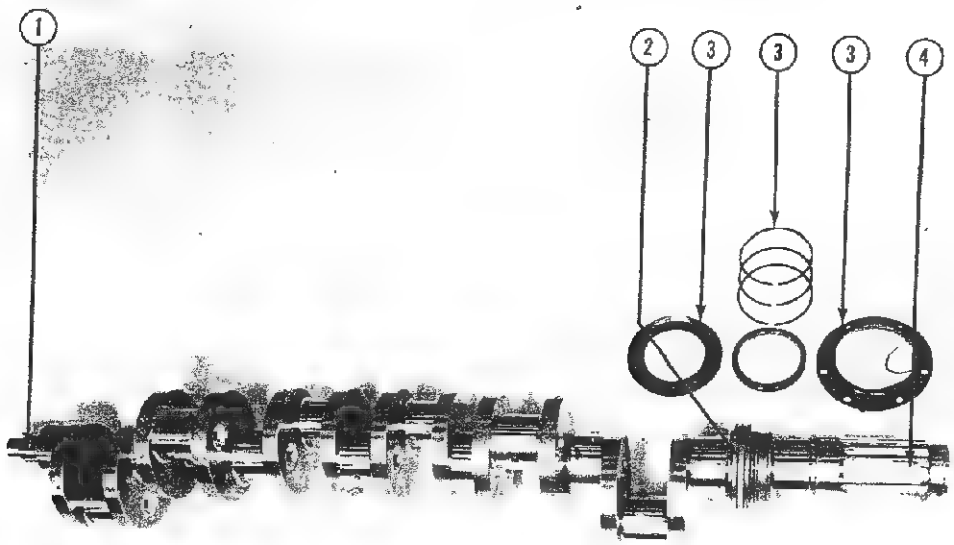

25X1B

0102 - CRANKSHAFT - ENGINE [redacted]

1. Spline for accessories drive, and crankshaft oil supply inlet
2. Ball thrust bearing
3. Rear oil seal assembly
4. Fan and clutch spline

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ENGINE PISTON AND CONNECTING ROD ASSEMBLY

A main and auxiliary connecting rod system was used on this engine, rather than both connecting rods (of each pair) operating directly on the crankshaft journal. This arrangement helped to make the engine shorter and lighter than otherwise would have been possible.

The pistons had five rings. Two of them were compression type and three were oil seal rings. All rings were 2.5 mm in height. The piston top was curved to improve fuel distribution and combustion. The lower edges of the two bottom oil ring grooves were chamfered and drilled to permit oil scraped from the cylinder walls to collect and return to the crankcase. The underside of the piston top was finned, probably to aid in cooling and to give strength to the piston top. The piston pin bosses were recessed on the outside to reduce weight and small holes were drilled through to the inside of the piston to return collected oil to the crankcase. The piston was pinned to the connecting rod with a hollow steel pin. This pin was a press fit in the piston bosses at room temperature. Piston pin bosses were drilled to permit oil to reach the pin. This indicates that the pin may have been intended to float at operating temperatures. The connecting rod bushing was a running fit. Piston pins and the cylinder walls were lubricated by oil thrown from the crankshaft.

Pistons shown in the German report had six rings. The ring that was later omitted was a 5 mm oil scraper ring that had been located immediately above the piston pin bosses. The Aberdeen tank had five rings.

The auxiliary rod was pinned to the main rod by a hollow steel pin, which was pressed in and held in place by a large cap-type screw. This screw was locked to prevent loosening by a thin brass washer with a tab which was bent up into a notch in the screw head. Any tendency of the screw to loosen would not meet much resistance from the brass washer. Considering the tendency of the Russians to securely lock every nut and bolt that could possibly come loose, it is peculiar that they should depend upon this type of lock for such an important application as a connecting rod pin.

The main rod bearing cap was fastened to the rod by six studs. The studs were screwed into the connecting rod and were then drilled and pinned to lock them. The nuts and bearing caps were marked after assembly to indicate how far the nuts should be screwed down (if the engine is later overhauled) to obtain the same torque setting that was originally used. The nuts were machined all over and were individually numbered to correspond with numbers on the bearing cap so that, if the engine is later overhauled, the nuts can be returned to the same studs they were removed from. Nuts were locked by cotterpins.

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Engine Piston and Connecting Rod Assembly

The pistons and piston pin plugs were made of a silicon-aluminum alloy. The connecting rods, pins, and bearing caps were of steel. Piston rings were cast iron and bearings were of copper alloys.

The connecting rods were forged, machined all over and hand polished. The pistons were also forged. Part of the inside of the piston skirt had been milled, probably to help balance the assemblies and reduce their overall weight. The milling was not evenly done, the result being uneven wall thicknesses on opposite sides of the piston skirt. Dimensional checks on several pistons revealed such random variation in wall thickness as to indicate that this unevenness was not intentional. The piston diameter was 150 mm and height was 120 mm.

The piston pin bushing on the main connecting rod and both bushings on the auxiliary rod were cast bronze and were held in the rod bores with hollow rivets. The main connecting rod bearings were steel backed lead copper inserts.

The piston pin plugs were turned from silicon-aluminum bar stock. They were not fastened to the piston pin, but floated loosely between the pin and the cylinder wall.

The main connecting rod assembly could not be easily removed from the upper crankcase because openings in the crankcase were not large enough to permit passage of either the piston or the large end of the main rod. To remove one of the main rod assemblies, it would be necessary to (1) pull the piston pin, separate the piston from the rod, and remove the rod through the bottom; or (2) remove three of the six studs at the large end of the connecting rod and remove the assembly through the top. Before the studs can be removed, however, it is necessary to drill out the pins that lock them.

All parts in the assembly were well made and, judging from the number of inspection stamps, had been carefully inspected. It is apparent that the Russians had recognized the need for dependability of these parts and had made them with extreme care to provide that dependability. Pistons and bearings showed very little wear on either engine.

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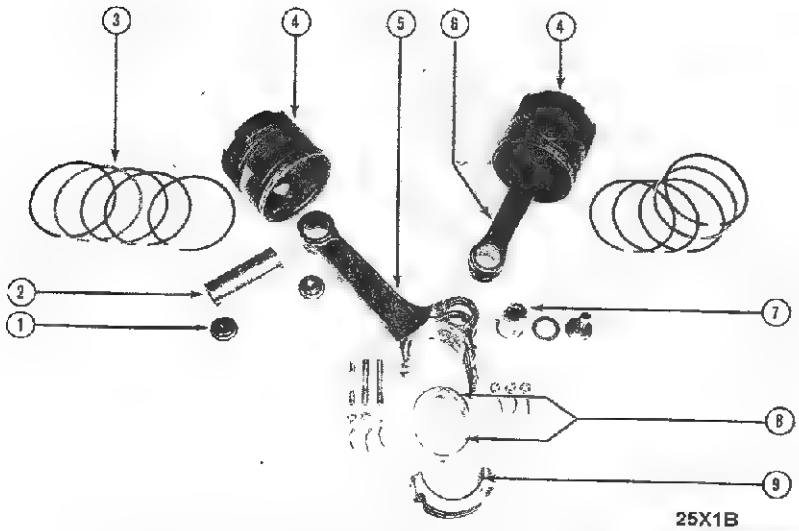

25X1B

0104 - PISTON AND CONNECTING ROD ASSEMBLY - ENGINE [redacted]

1. Connecting rod piston pin cap
2. Connecting rod piston pin
3. Piston rings
4. Piston
5. Main connecting rod
6. Auxiliary connecting rod
7. Auxiliary connecting rod pin
8. Main connecting rod bearing liners(shells)
9. Main connecting rod bearing cap

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ENGINE - INTAKE AND EXHAUST VALVES

These valves were of the same design as that used on the original Hispano Suiza engine. The valve adjustment is made by screwing the tappet in or out of the hollow valve stem. The tappet is locked by a serrated disc, which is splined to the valve stem and held in contact with the tappet by the valve spring.

25X1B

On the spare engine [redacted] the valves were locked to prevent rotation by ears or lugs on each end of the larger valve spring which fitted into notches in the cylinder head and the tappet lock.

The engine removed from the tank was not provided with this anti-rotation device, and the valves were allowed to turn freely. Even on that engine, however, it appeared as though the valves did very little turning, having moved only two or three times in the life of the engine. Apparently this movement was an occasional jump rather than a steady rotation.

25X1B

25X1B

The valves and tappets were forged steel. Valve springs on the spare engine [redacted] were zinc plated and on engine [redacted] were oxide coated. The valves appeared to be well made, except that threads in tappets and valves did not fit well.

The valves are adjusted by removing the head covers and using a special wrench to disengage the tappet lock serrations and turn the tappet.

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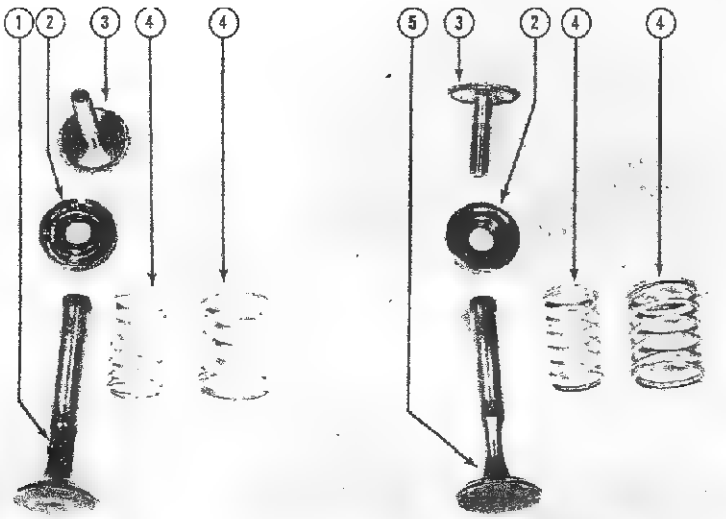

25X1B

0105.1.0 a - VALVES - ENGINE [redacted]

1. Exhaust valve
2. Spring seat and tappet lock
3. Valve tappet
4. Valve springs
5. Intake valve

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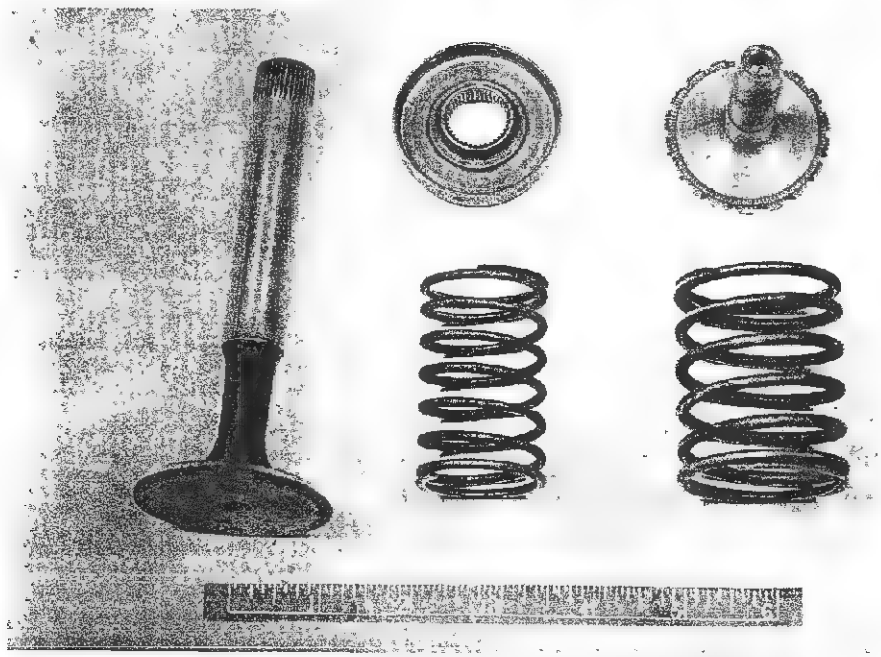

0105.1.1 - VALVE - ENGINE [redacted] 25X1B

[redacted]

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ENGINE - CAMSHAFTS

The intake camshaft, driven by one of the accessory drive shafts, carries a gear cluster consisting of a spur gear and a bevel gear. The exhaust camshaft is driven from the spur gear. Timing of the individual camshafts is provided for by splined sleeves between the camshafts and driving gears. The sleeve is held in place by a notched head bolt and can be backed out, allowing the sleeve and camshaft to turn while the gear remains stationary. The gears are located concentrically on the camshaft by riding on the shoulders provided. The splines are therefore subjected to torque load only.

Oil is supplied to the hollow center of these camshafts through the large hole in the journal nearest the gears, which receives oil through a groove in its bearing. There is a continuous discharge of oil from each of the individual cams and at each of the other six bearing journals on each camshaft. The oil feed holes are .040 inches in diameter.

The individual cams are alike on all four camshafts but are located differently on exhaust and intake camshafts because of different rotation directions. Valve lift provided by the cams is .510 inches. The tachometer drive is driven from the right intake camshaft through a tongue provided on the front oil plug, which fits into a slot on the tachometer drive input shaft.

The camshafts were forged roughly to shape before machining. They were case hardened on the cam surfaces only.

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25X1B

0105.3 - CAMSHAFTS - ENGINE [redacted]

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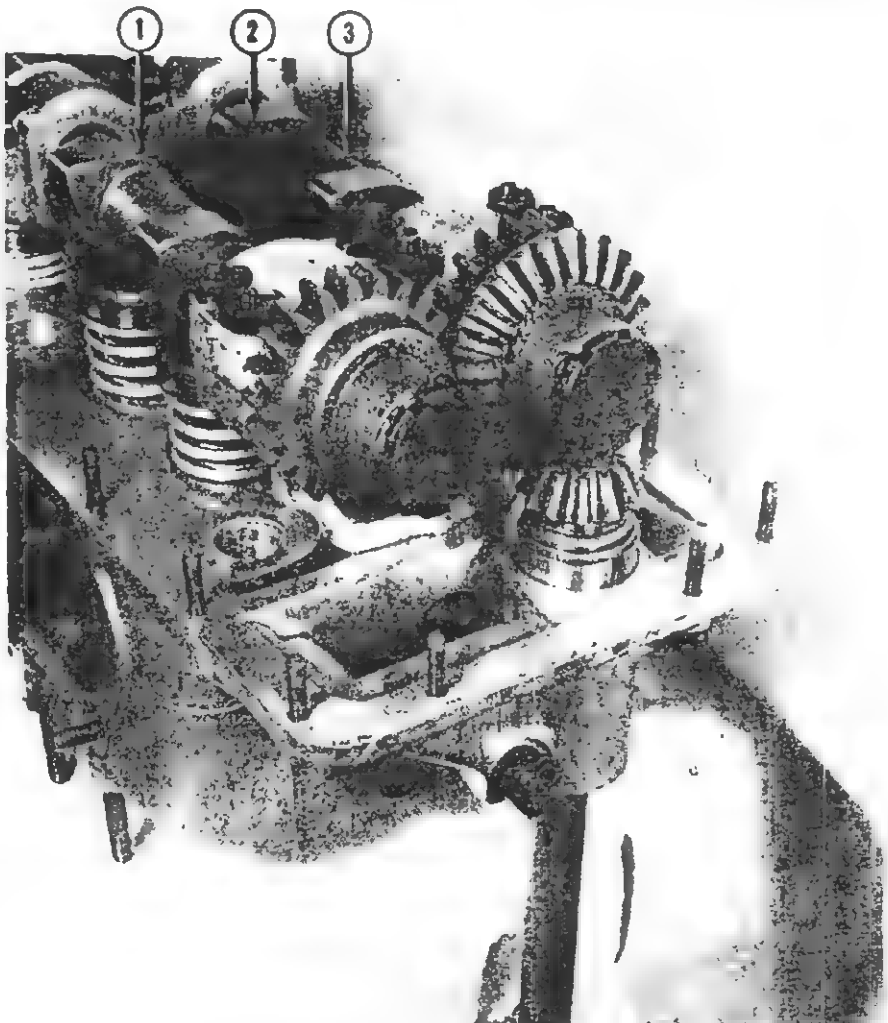

25X1B

0105.4 - LEFT CAMSHAFT DRIVE ASSEMBLY - ENGINE [redacted]

1. Exhaust camshaft
2. Fuel injection nozzle
3. Intake camshaft

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ENGINE - INTAKE MANIFOLDS

Intake manifolds were made of stamped steel parts welded together. Note that the intake manifolds shown are from different engines. On the older engine, four bosses were provided for the attachment of other parts, whereas on the newer engine there were only two such bosses. The front-most bosses (extreme right in photograph) were to support the fuel filter on both manifolds. The rearmost boss on the older manifold was used to support the water radiator filler tube.

25X1B

No provision was made to support the filler tube on engine [redacted] although the filler tube provided with the engine had the same type of bracket that was used on engine [redacted]

25X1B

The two middle bosses on the older engine were not used and appear to have been provided to support the old hat-type air cleaner, even though that cleaner was no longer used and other modifications of the manifolds had been made to accommodate the new type cleaner.

On the newer manifold, the second boss was not provided. Apparently the matter of eliminating bosses had been confused, and it appears as though one of the bosses removed was the wrong one.

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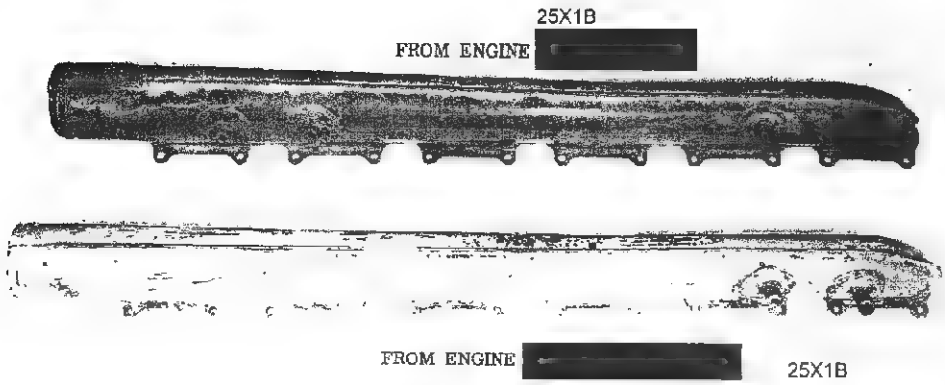

0108.0 - INTAKE MANIFOLDS

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ENGINE INSTRUMENT PANEL

The G812 tank had a panel providing four circular openings for gauges. Three of these were occupied as follows:

Water temperature gauge	O-125 C
Oil temperature gauge	O-125 C
Oil pressure gauge	O-15 atmospheres

The fourth opening at the extreme left was unoccupied but had been intended for the engine tachometer, judging from the accompanying data on engine operating speeds. The tachometer, however, was found to be mounted on the same panel as the speedometer, just as had been noted in the Aberdeen report. It appears as though the tachometer may have been moved from the earlier location to the engine instrument panel, and then back to its original location in still later production.

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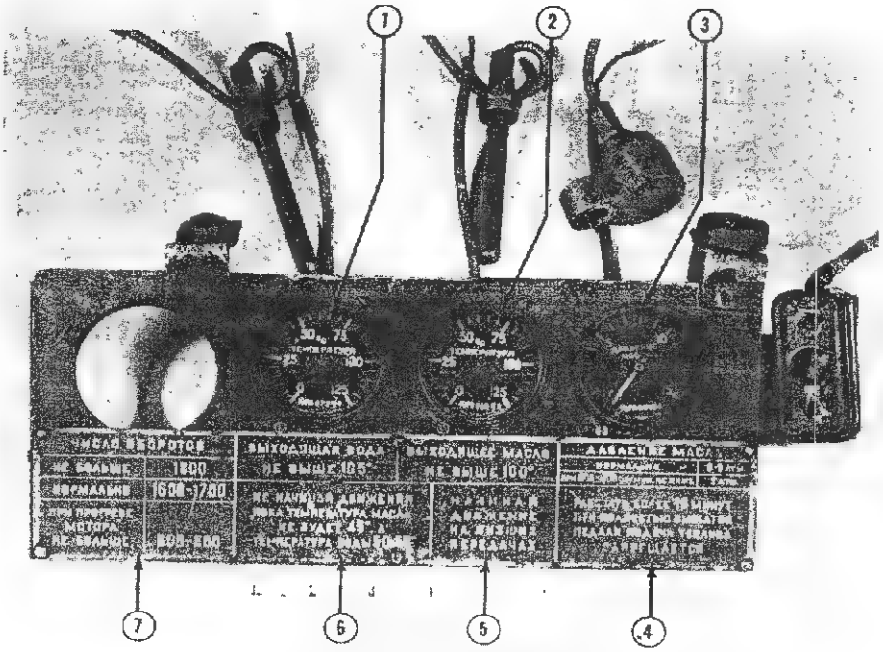

0106.6.5 - ENGINE INSTRUMENT PANEL

1. Water temperature gauge
2. Oil temperature gauge
3. Oil pressure gauge
4. Translated as follows: "Oil pressure
   Normal 6.9 atmospheres
   At 600 800 rpm not less than 2 atmospheres
   To be run more than 10 minutes with com - pletely depressed clutch at idle speed.'
5. Translated as follows: "Outlet oil at not more than 100°.
   Start movement in low gears."
6. Translated as follows: "Outlet water at not more than 105°.
   Do not start movement until oil temperature reaches 45° and water temperature 50-55°.
7. Translated as follows: "Number of Revolutions
   Not more than 1800
   Normal 1600-1700
   Warming up
   motor
   not more than 600-800."

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ENGINE LUBRICATION SYSTEM

One oil supply tank of 17.5 gallons capacity was located on each side of the engine. The tanks were filled from outside the hull, through armor-plate-covered access openings. The tank inlets were covered by removable caps. These caps were also pressure relief valves. Output lines from the two tanks joined and supplied oil to the hand operated oil pump and the high pressure bank of the engine operated oil pump.

The engine operated oil pump forced the oil through the oil filter to the oil manifold on the front of the engine, at a pressure regulated by a built-in relief valve. The oil filter also had a pressure relief valve, to by-pass oil in case the filter element became plugged. The oil manifold distributed the oil to the various engine components and to the crankshaft journals. The oil, after lubricating the various engine parts, was drained to the crankcase. The two low pressure banks of the oil pump received the oil from the crankcase and pumped it to the scavenge oil control valve, which directed it either to the oil filter and engine or to the oil radiator. Oil from the radiator was then piped back to the supply tanks.

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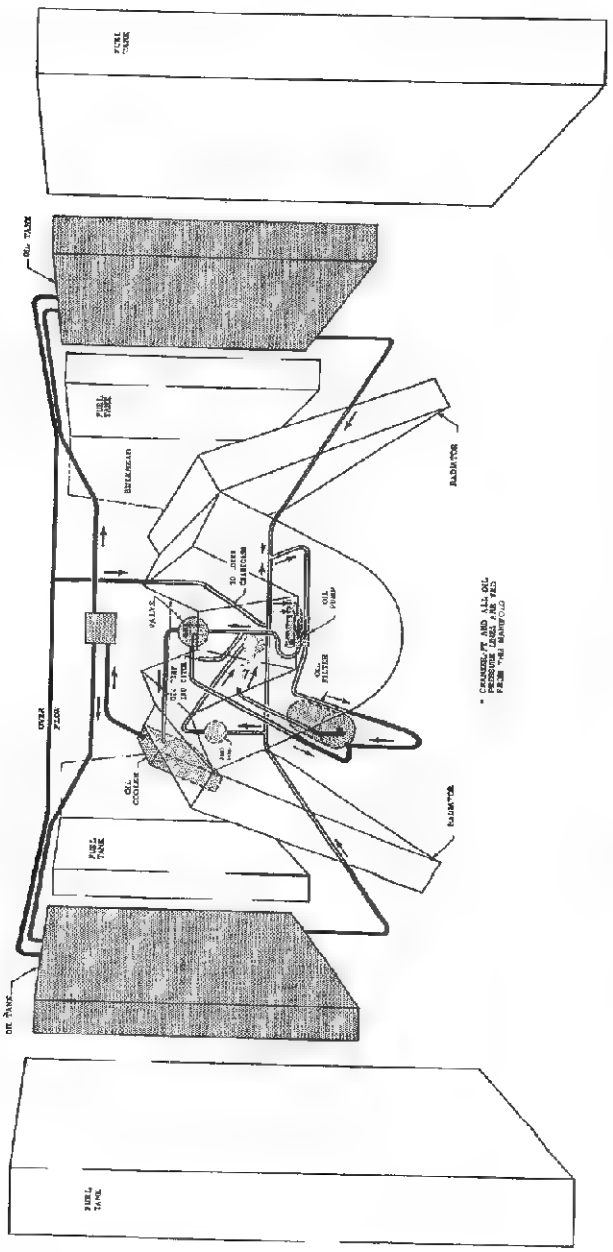

0106 - ENGINE LUBRICATION SYSTEM
LOOKING FORWARD FROM REAR OF TANK

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ENGINE LUBRICATION SYSTEM - ENGINE DRIVEN OIL PUMP

This three-bank gear type pump serves two purposes: (1) to deliver oil under pressure to the oil filter and from there to the oil manifold at the front of the crankshaft; and (2) to remove all oil from the lower crankcase. This oil is normally sent to the oil radiator and from there to the oil tanks but can be directed to the oil filter for increasing the supply to the crankshaft. The scavenge oil control valve provides this selective control.

The pump is located under the lower crankcase near the front of the engine and is driven from the same accessory drive train that drives the fuel transfer pump and water pump.

High pressure supply is provided to the oil filter by the lowest gear bank of the pump. Pressure is controlled by an adjustable pressure relief valve. The other two banks provide the low pressure oil supply to the radiator. The uppermost bank removes oil from the front of the crankcase and the middle bank input is connected to a sump at the rear of the crankcase. Sump draining is thus provided for, during operation at an angle.

The low pressure inlets are covered by a perforated metal screen, which could be expected to remove only large chips of metal. The Aberdeen report showed a cup shaped screen which covered the entire pump top. The screen on both G812 pumps covered only the inlet port. In the pump from engine [redacted] conventional square keys connected the driving shaft to its gears. In the pump from engine [redacted] flat keys were used instead.

25X1B

25X1B

All body members of the pump are permanent mold silicon-aluminum alloy castings. All other parts are steel, except for the copper-alloy bushings in the driven gears, which turn on a fixed shaft.

The pump is easily reached for servicing. A plate in the hull bottom can be removed from beneath the tank, exposing the oil pump for easy removal.

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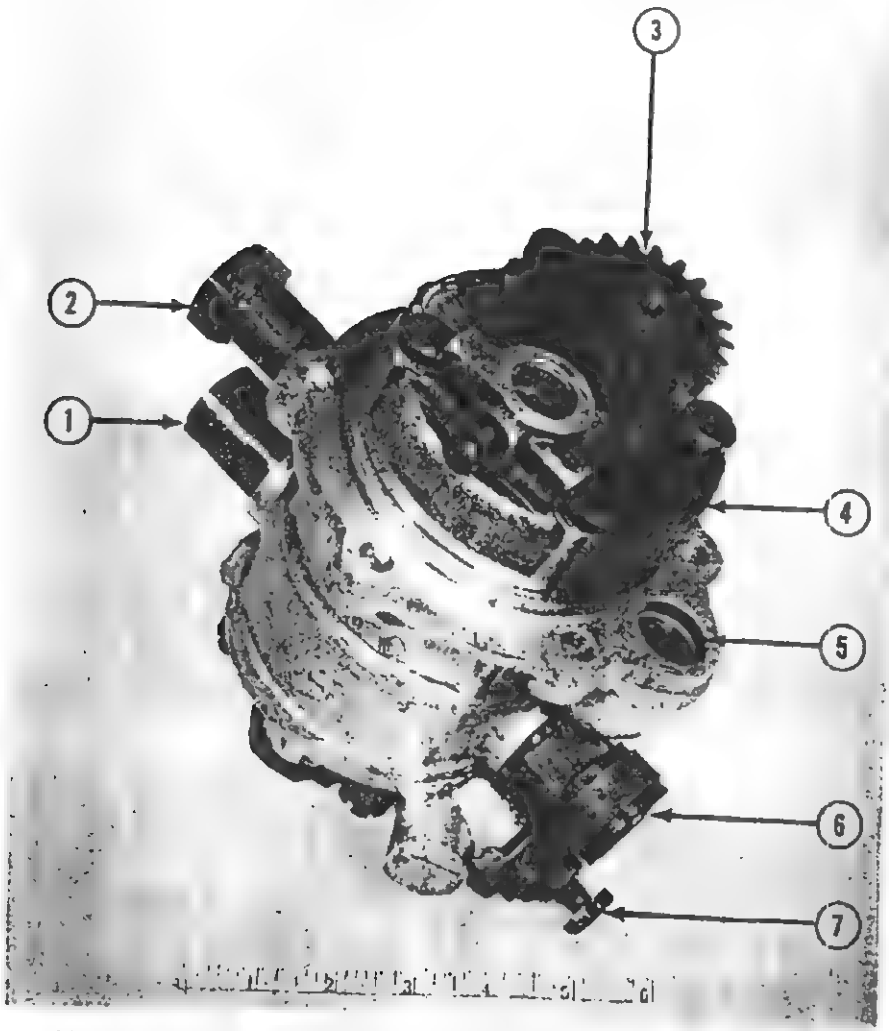

0106.1 a. - ENGINE LUBRICATING OIL PUMP - ENGINE [redacted] 25X1B

1. Outlet to oil filter
2. Oil to scavenge oil control valve
3. Drive gear
4. Inlet from front of lower crankcase
5. Inlet from rear of lower crankcase
6. Inlet from oil tanks
7. Pressure regulating by-pass valve

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ENGINE LUBRICATION SYSTEM

HAND OPERATED OIL PUMP

This small piston-type pump receives oil from the oil tanks and supplies it to the oil manifold on the front of the engine. The pump is hand operated and is of such small capacity that it would be of little use in the event of failure of the engine driven oil pump. It could, however, be used to pump oil to the engine before it is started, thus insuring enough lubrication to avoid scoring and scuffing. The pump is located at the rear of the fighting compartment and would be operated by the fighting crew rather than the driver or machine gunner.

The pump body is made of cast iron. The piston is of cast iron or steel and is provided with two felt rings. The pump valves are two spring loaded ball checks.

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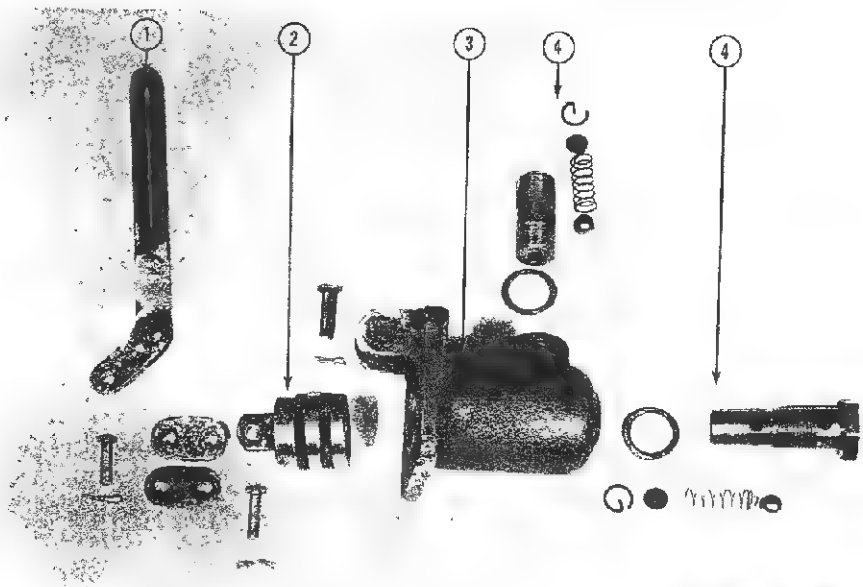

0106.1.3 b - HAND OPERATED OIL PUMP ASSEMBLY - ENGINE 25X1B

1. Handle
2. Piston
3. Body
4. Check valves

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ENGINE LUBRICATION SYSTEM - OIL FILTER

The three filter elements in this assembly were found to be in parallel. A pressure relief was provided to by-pass oil if the filter became clogged.

The filter elements were of the edge-type, being formed by winding a narrow brass strip edgewise into a closely packed helix. Depressions rolled into the strip provided clearance space of .0032-.0040 inches for the oil to pass through. The lands which were allowed to remain between the rolled depressions served to space the successive turns of the helix.

The oil filter assemblies on the two G812 engines differed slightly. 25X1B
Both had sand cast aluminum-alloy filter housings, but the methods of support of the wound helix were different. In the filter from engine [redacted] the inner wall of each element was formed by the cast aluminum cylinder on which the ribbon was wound. Ribs cast on the outside of these aluminum cylinders provide oil flow space. The inner wall of each element in the
25X1B filter from engine [redacted] was formed of a corrugated fiber-like paper cylinder.

The German report describes a "light alloy oil filter" consisting of a sieve circuit with 20 circular sieves through which the lubricating oil flows. They also give the total filtering surface area as 800 square centimeters, or 52 square inches. The two G812 filters each had a total filter area of 215 square inches. The filters mentioned in the German and Aberdeen reports were mounted on bosses cast integrally with the lower crankcase. The filters on the G812 engines were mounted on cast iron brackets which bolted to the upper crankcase. Two of the bosses on the lower crankcase formerly used for the oil filter now support the water pump lubrication assembly.

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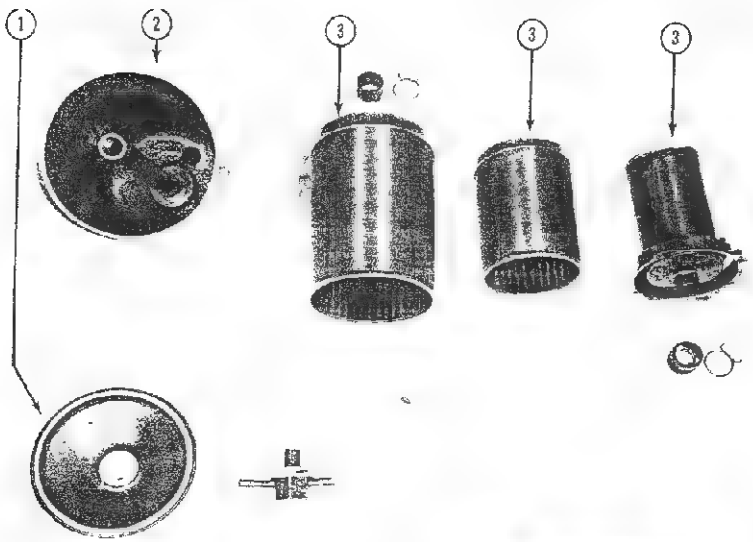

25X1B

0106.2.1 - OIL FILTER - ENGINE [redacted]

1. Cover
2. Housing
3. Filter elements

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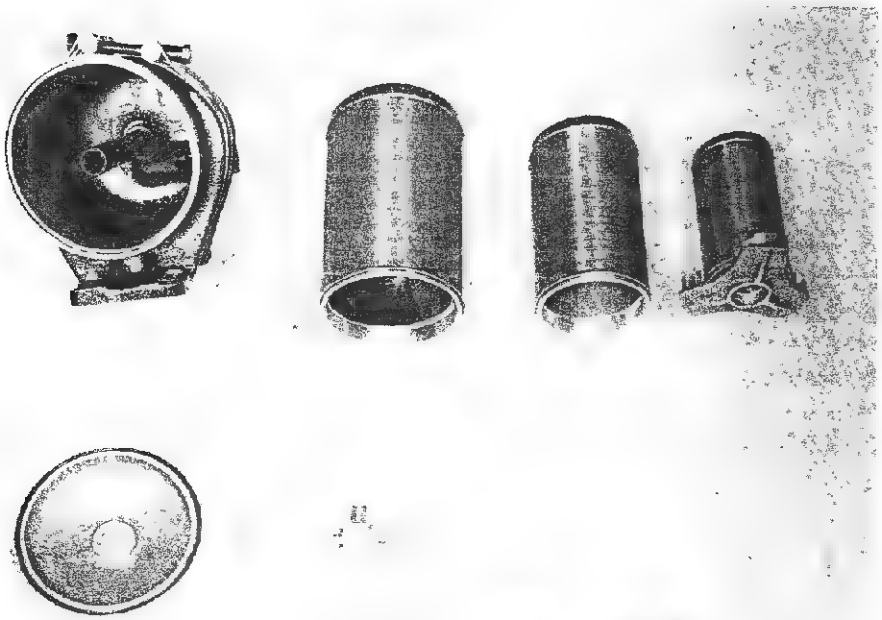

25X1B

0106.2.2 OIL FILTER - ENGINE [redacted]

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ENGINE LUBRICATION SYSTEM - OIL RADIATOR

This radiator appears to be made of the same core that is used for the two-tube section of the water radiator core. End tanks are made of drawn steel. The tanks are partitioned to force the oil to go the complete length of the radiator four times. Inlet and outlet fittings are on the same end tank. This tank is provided with a by-pass pressure relief valve to permit oil to go from inlet directly through the tank to the outlet, in case the radiator becomes plugged. Pressure in the oil radiator would probably be quite low, since only the resistance of oil flow through it would create back pressure. The radiator is supplied from the low pressure, high capacity side of the oil pump.

The cooling area of the oil radiator is approximately 500 square inches. The core is 1-5/8 inches thick and capacity of the radiator was 3.3 quarts.

The German report mentions "one oil cooler for each cylinder bank." The Aberdeen report made no mention of an oil radiator, nor did the photographs show one.

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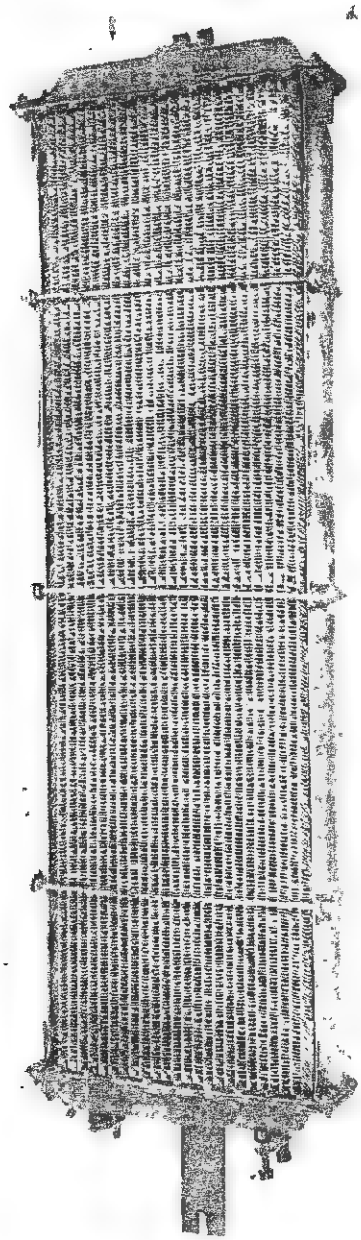

0106.3.1 - OIL RADIATOR

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ENGINE LUBRICATION SYSTEM - SCAVENGE OIL CONTROL VALVE

This cylindrical plug cock valve is used as a two-port three-way valve. The long tubular connections brazed to the valve body are in vertical position on the engine, the left end in the photograph being on the bottom. Oil enters this lower end from the sump pump output, flows past the oil temperature fitting shown entering at an angle, and may then be directed by this valve to the oil radiator or directly to the oil filter, and so back into the engine. When the latter connection is established, the sump pumps operate at engine oil pressure, control being provided only by the pressure relief valve that normally serves the oil pressure bank in the oil pump. This provision of recirculating the sump oil can serve to accelerate the adequate supply of oil to all points in the engine when first starting and to speed the warming-up of the engine.

The valve body is brass. The valve plug is steel, as are the connecting tubes brazed to the body. After the tubes were brazed in place, the valve body and tube assembly was lead dipped. There is no lead on the inner surface, however, and the steel plug works directly in the brass body.

The valve is fastened to the engine fighting compartment bulkhead and is controlled from the fighting compartment.

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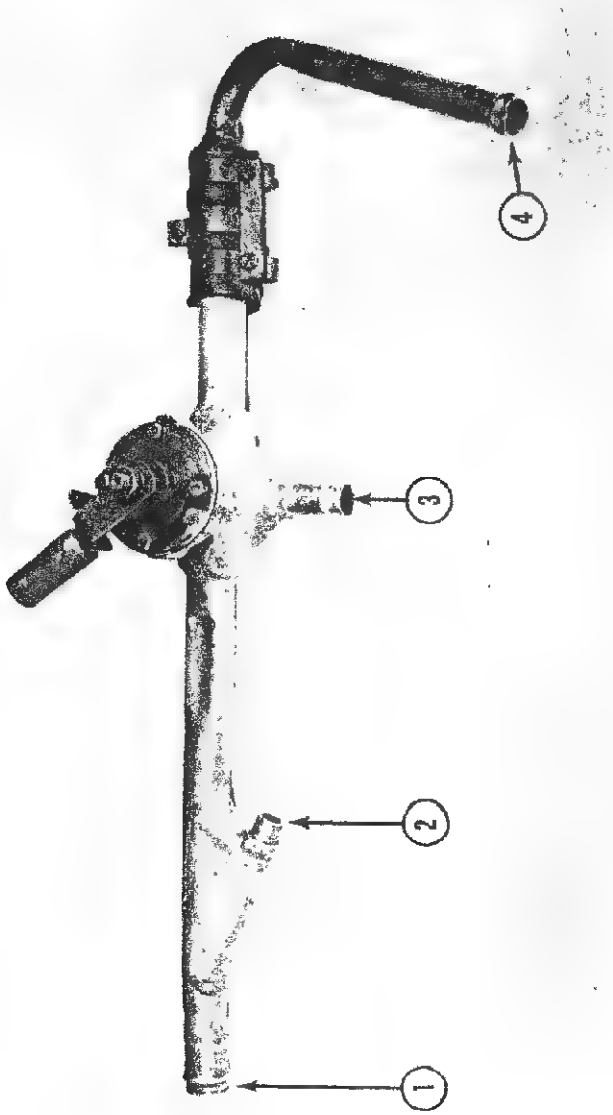

0106.6.1 a - SCAVENGE OIL CONTROL VALVE

1. Inlet from oil pump
2. Connection for oil temperature gauge
3. Outlet to oil filter
4. Outlet to oil radiator

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ENGINE LUBRICATION SYSTEM - OIL MANIFOLD

This manifold serves as a means for providing connection between the lubricating oil supply and the crankshaft. Oil coming through this entry is also piped off in several directions to provide a supply to other parts of the engine.

The flanged assembly is bolted directly to the crankcase, straddling the two halves of the case. There is also an entry port from a hand operated oil pump. There is no check valve to prevent the oil from the hand operated pump from flowing backward into the oil filter, and from there into the engine operated oil pump.

25X1B

On the crankcase on the [redacted] engine, there was an additional port for outgoing oil which directed oil to the group of gears driving the fuel transfer pump, water pump, and the oil pump. The connection to this port in the crankcase was made through a drilled passage added to the oil manifold, requiring no outside piping in this case. The other major oil feed lines were provided by outside pipes, however, with all of the attendant risk of the developing of a leak under the severe vibration encountered.

Connection to the crankshaft was provided by a brass bushing having running fit with the end of the crankshaft and a flange that seated against the inside face of this oil manifold assembly. Apparently oil pressure was counted upon to push the bushing flange against the face of the housing to provide a seal. There was no spring to hold the bushing in place before oil pressure was developed. The bushing was allowed over .030 lateral movement to provide for imperfect alignment between the crankshaft and the oil manifold. The bushing was retained, however, with an internal expanding snap ring so that no more than .050 axial movement could occur. Apparently sufficient oil pressure was developed in this manifold even with the bushing away from its face seat to insure that the bushing would be pushed onto its seat.

The oil manifold body was cast iron. The inner flange was steel with a carburized and hardened surface at the brass bushing running surface.

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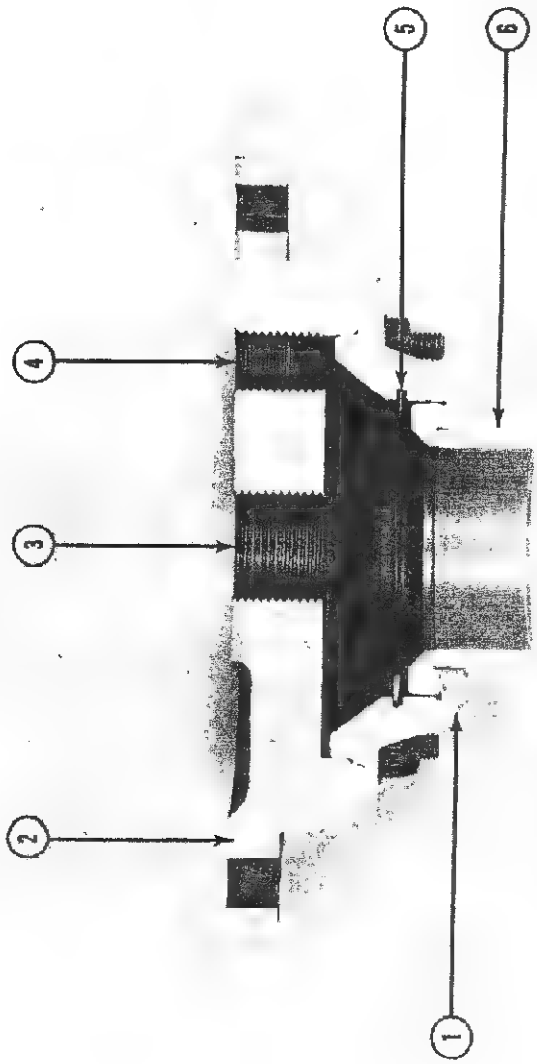

0106.6.3 c - OIL MANIFOLD, SECTION VIEW

1. Steel flange
2. Cast iron body
3. Oil inlet from oil filter
4. Oil inlet from hand-operated pump
5. Bushing retainer ring
6. Floating brass bushing

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ENGINE LUBRICATION SYSTEM

HOLLOW CHAMBER

The lower connection of this empty vessel was attached to the output line from the oil radiator. The upper connections went to the two oil tanks.

The vessel was welded all over, with no means provided for access to the contents. One possible use of the chamber is to trap water vapor. The chamber was found in a high point in lines joining the oil radiator and the two oil storage tanks. Water vapor rising into the chamber would condense and drop to the bottom where, if it froze, no harm would be done. Later operation of the tank, with consequent rise of the oil temperature to and above the water boiling point, would automatically dispose of the entrapped water.

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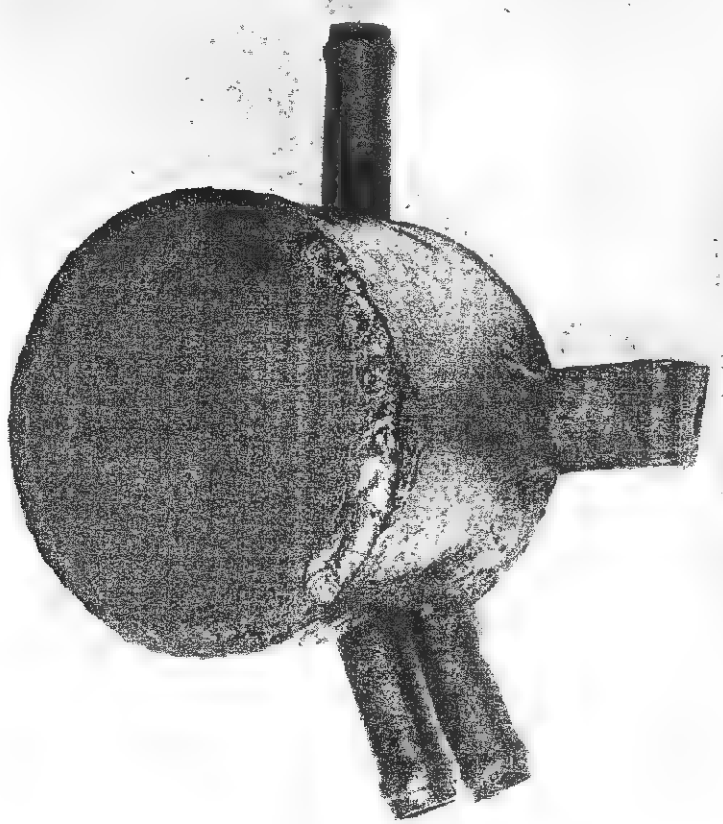

0106.7 a - HOLLOW CHAMBER IN LUBRICATING OIL LINE BETWEEN RADIATOR AND OIL TANKS

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AIR STARTER SYSTEM DISTRIBUTOR

This distributor serves as a rotary valve to connect a supply of high pressure air to the several engine cylinders in proper sequence. The high pressure air (1000 psi) comes from two storage cylinders in the hull. Steel tubing is used for all connections to and from the air distributor. Check valves located at the tubing fittings leading into the cylinder heads prevent reverse flow of combustion products when the cylinders begin to fire.

The distributor is interposed in the drive train leading to the fuel injection pump. It is timed by the use of a drive bushing that is splined both internally and externally to permit differential adjustment. This timing setting also affects the fuel injection pump, since the drive to this pump is through the distributor. An adjustment for the injection pump alone can then be made at the coupling joining the pump to the distributor.

The rotary slide valve is spring loaded. There is no seal other than provided by the metal-to-metal fit, which is excellent.

About 120 degrees duration is provided for air injection, the valve opening occurring at about 6 degrees before top center.

This distributor, with its bevel gear drive, is provided with pressure lubrication through a drilled channel. The shaft to the injection pump is provided with a spiral groove intended as an oil retainer.

The distributor housing and cover are aluminum alloy sand castings. The steel shaft at the output to the injection pump runs directly on the casting. The gears are shaper-cut. The internal and external splines serving to provide differential adjustment for timing were very well machined. The mating faces of the rotary valve parts were very smoothly ground. They showed virtually no wear.

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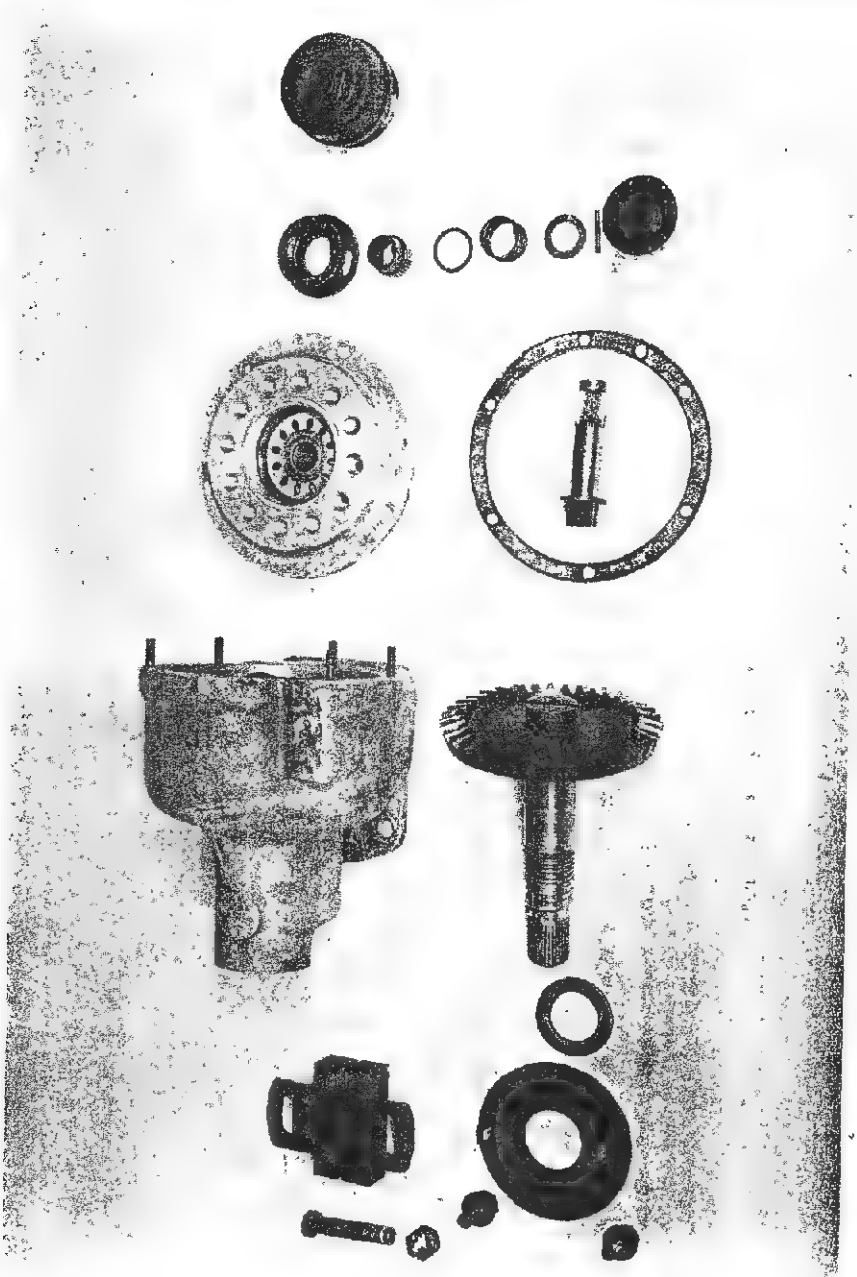

0107 e - AIR STARTER DISTRIBUTOR ASSEMBLY

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AIR STARTER SYSTEM CHECK VALVES

These valves (one per cylinder) screw directly into the cylinder head and lead to the air discharge passage that opens into the combustion space. These valves allow compressed air to enter the cylinders during air starter operation, but prevent combustion products from flowing back into the air starter during regular firing operation. Both the valve and the seat appear to be ground. The guide lands on the valve stem are a close fit in the valve bore. Note that the spring is square ended, having been wound in this manner and ground.

The member serving as spring seat and nut is knurled to facilitate assembly without tools. This nut is held to the valve stem by a cotterpin. Both nut and stem are drilled, and there is no provision for adjustment unless this drilling is done after assembly, with each spring being set to provide proper compression.

The check valves found in the [redacted] engine were the same as those in engine [redacted]

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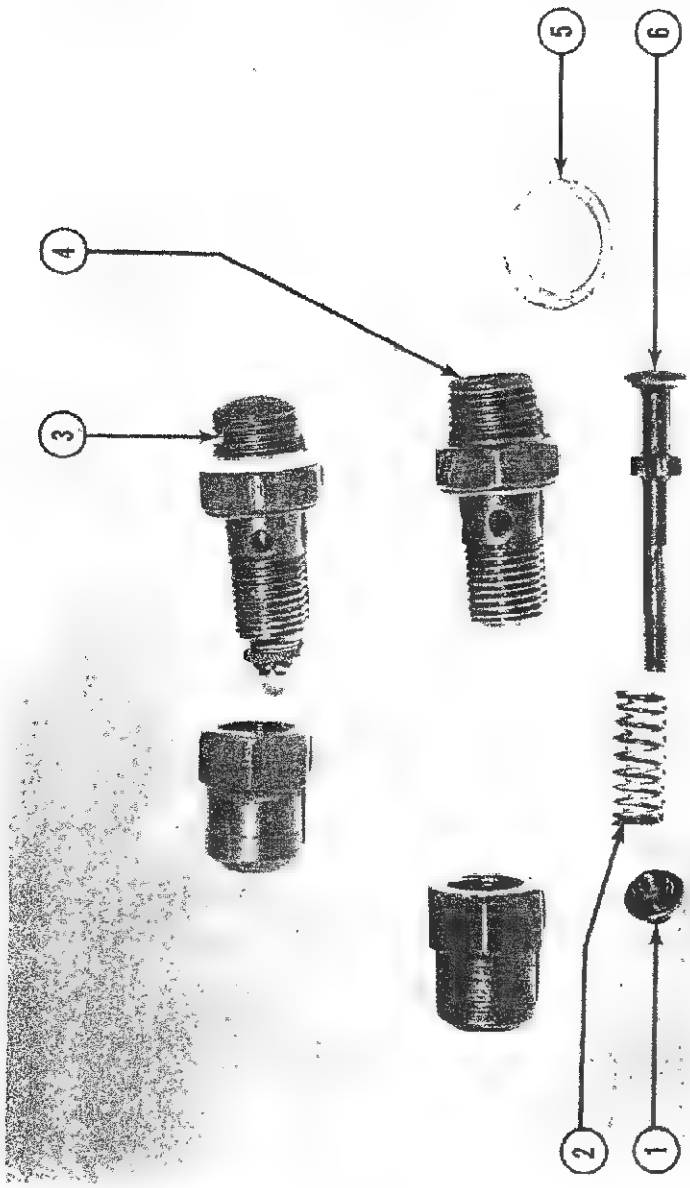

0107.3 - AIR STARTER SYSTEM CHECK VALVES

1. Spring seat and nut
2. Valve spring
3. Assembled valve
4. Valve body
5. Metal gasket
6. Valve

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ENGINE - ACCESSORY DRIVE SYSTEM

The main accessory drive gear (item 1) is splined to the crankshaft in back of the oil inlet bearing and drives the whole accessory system. This gear, although splined, is not tightly fastened to the crankshaft but is permitted to slide on the splines in case end play of the crankshaft occurs. The gear is retained by accessory drive gears in front and by a hardened forged steel plate at the rear. The plate is provided with passages to permit oil leaking past the first main bearing to escape to the crankcase.

The generator drive (items 2, 3, and 4) consists of a series of bevel gears and shafts. The two shafts run on aluminum alloy bearings. The final output shaft to the generator has a helical groove machined in it to help reduce the amount of oil that leaks past the bearing. No other seal is provided here. The speed ratio of generator to engine is 1.5 to 1.

The upper accessory drive shaft assembly (item 5) is supported at the top by an aluminum alloy bearing and at the bottom by a self-aligning, double ball bearing. The lower bevel gear runs on the main accessory drive gear. The smaller bevel gear, near the middle of the shaft and made integrally with the shaft, drives the camshafts. The upper gear drives the air starter distributor which is, in turn, coupled to the fuel injection pump and governor. The camshafts, air starter, distributor, fuel injection pump, and governor all run at 0.5 engine speed.

The bevel gear shaft (item 10) is splined to the spur gear shaft below it (item 15) which drives the water pump, oil pump, and fuel transfer pump. Both shafts run on aluminum alloy bearings cast integral with the lower crankcase. The water pump (item 14) is coupled directly to the gear and runs at 1.5 engine speed. An idler gear (item 13) to drive the fuel transfer pump is driven by the spur gear. The idler gear consists of two parts; a spur gear and a smaller bevel gear pressed into the hollow spur gear. Another bevel gear, coupled directly to the fuel transfer pump, is driven by the first bevel gear. Fuel transfer pump speed is 0.7857 engine speed. The oil pump (item 17) is driven through an idler gear (item 16) which is supported by a ball bearing. The oil pump is driven at 1.725 engine speed.

All bevel gears are adjusted laterally with steel washers or, when the gear shaft runs on a removable bearing, paper gaskets.

All gears checked were made of Krupp steel. No failures or signs of failures were noted on these gears on either engine examined. The life of the lower gears may have been greatly lengthened by the addition of the lubricating oil connection provided by the newer oil manifold described earlier. The fact remains, however, that the gears from the older engine, which was not provided with this extra oil connection, were also in excellent condition.

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0109.1 - ENGINE ACCESSORY DRIVES - ENGINE [redacted]

1. Main accessory drive gear, splined to crankshaft (27 teeth)
2. Generator drive housing
3. Generator drive, output bevel gear assembly (18 teeth)
4. Generator drive, input bevel gear assembly (18 teeth on each end)
5. Air distributor and injection pump drive assembly
6. Air starter system distributor
7. Camshaft drive assembly from upper gear on air distributor and injection pump drive
8. Camshaft drive shaft
9. Steel plate behind main drive gear to maintain gear alignment
10. Lower accessory drive shaft, upper part (18 teeth)
11. Fuel transfer pump
12. Fuel transfer pump drive (21 tceth)
13. Fuel transfer pump idler gear (23 teeth input, 11 teeth output)
14. Water pump
15. Lower accessory drive shaft, lower part (23 teeth)
16. Oil pump drive idler gear (36 teeth)
17. Oil pump (20 teeth input)

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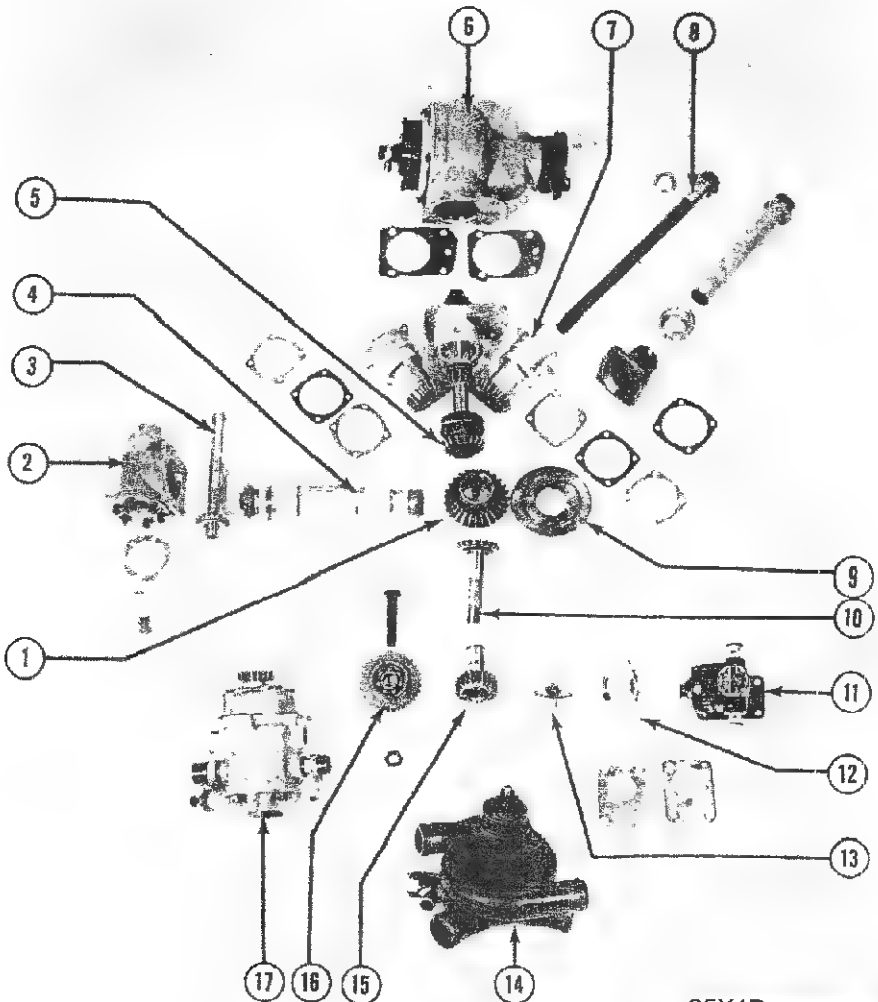

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0109.1 - ENGINE ACCESSORY DRIVES - ENGINE [redacted]

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ENGINE - TACHOMETER DRIVE

This small bevel gear pair serves to drive the tachometer flexible shaft. The input shaft has a self-aligning feature which consists of a short shaft pinned to the input shaft by a single pin. Movement of the camshaft tongue in a slot in the input shaft end provides the crosswise component of movement in case of mis-alignment. The bevel gears are spaced by steel washers.

The body is of aluminum alloy, cast in a permanent mold with sand core. Bearings are cast integrally with the body parts. The assembly is lubricated by oil splashed from the camshaft into two holes in the input bearing. The output shaft has a helical groove to help prevent oil leakage through the output shaft bearing. No other seal is provided at this point.

This assembly was fastened to the cylinder head cover by four studs. A red sealing compound consisting of iron oxide in a drying oil was used instead of a gasket. Paper gaskets were used to seal the output shaft pilot bearing body.

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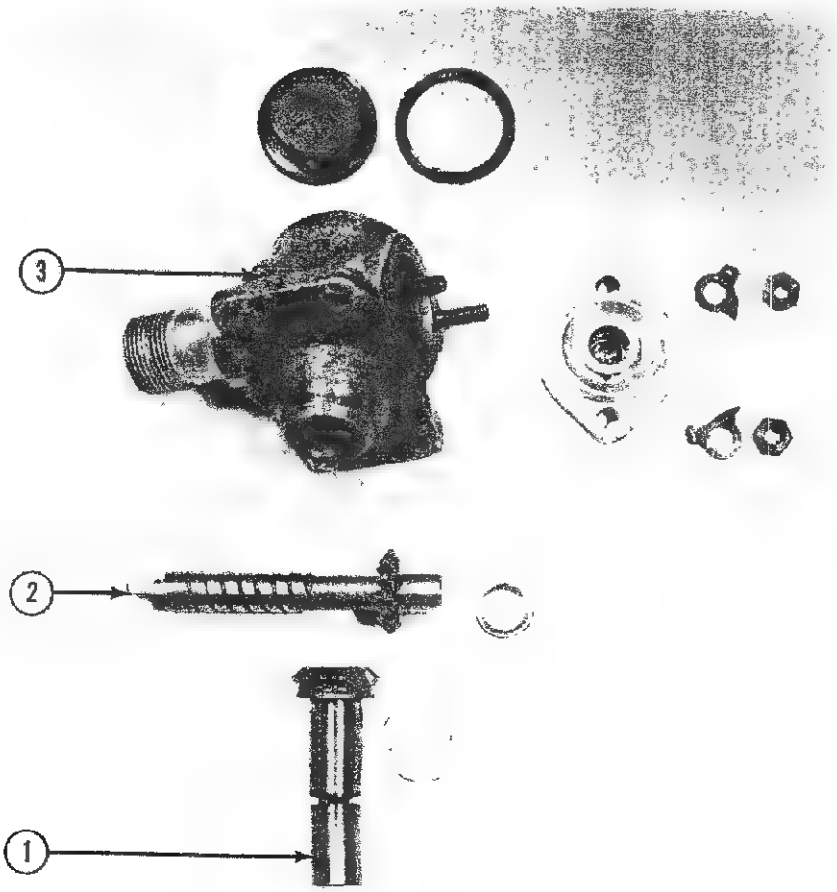

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0109.1.4 a - TACHOMETER DRIVE - ENGINE [redacted]

1. Input shaft from intake camshaft drive
2. Output shaft to tachometer cable
3. Body

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The main clutch consists of 22 alternate drive and driven discs, which were compressed by 16 springs. The pressure on the discs is relieved (to disengage the clutch) by compressing the springs with a ball and ramp arrangement. The drive discs are serrated on their outer edge to match similar serrations on the inner surface of the outer clutch drum. The driven discs are serrated on their inner edge and fit over teeth machined on the outer surface of the driven drum. The clutch output drum is splined to a flange which bolts to another flange splined to the transmission input pinion.

The Aberdeen report had indicated difficulty with clutch slippage. There was no evidence on the G812 tank that the main clutch or the final drive clutches had been slipping unduly. On most of the clutch discs, it was possible to see the original Blanchard-type grinding marks. The disc internal and external diameters had been lathe turned and teeth appeared to be shaper cut.

The fan is constructed of sheet steel parts, riveted together. The fan in the G812 tank was found to have the diameter of 35-1/2 inches. The Germans reported a fan diameter of 872 mm or 34-3/8 inches. The German report also describes the 30 blades as being 182 mm or 7-3/16 inches "high". The G812 fan blades, also 30 in number, are 6-3/8 inches wide. The width of the entire fan and flange assembly (without ring gear) was found to be 8-5/8 inches. If this were the dimension the German article referred to, it could mean that the G812 tank had a larger fan.

The starter ring gear was bolted to the rear of the fan. The complete assembly was apparently then balanced by drilling metal from the ring gear flange. The edge of the ring gear was marked all the way around with angular designations, probably to aid in timing the camshafts and injection pump.

The assembly is splined to the engine crankshaft and can go on only one way, because of a missing spline tooth and a matching obstruction on the crankshaft spline.

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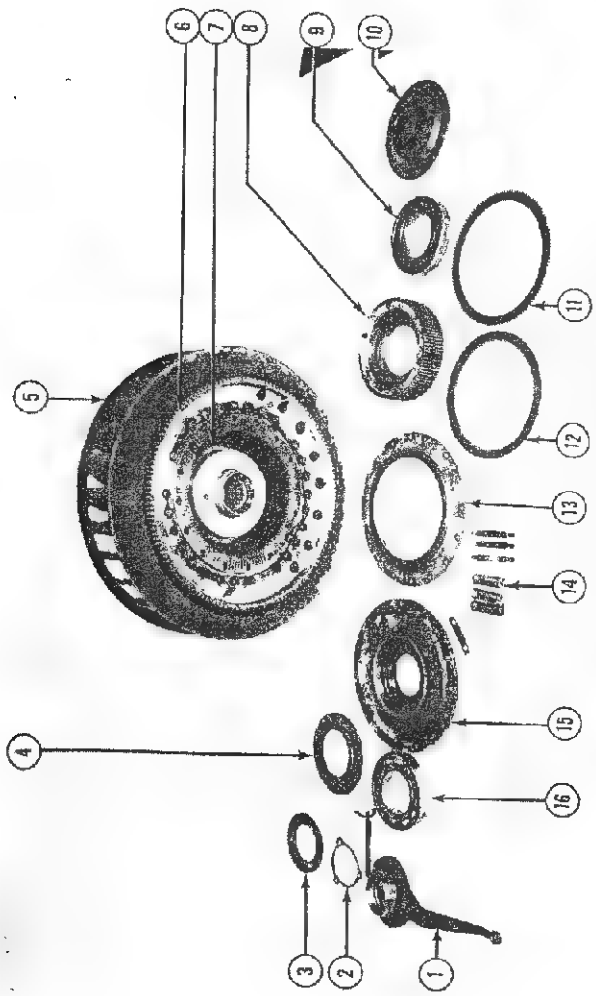

0200 b - CLUTCH, FAN, AND RING GEAR ASSEMBLY, REAR VIEW

1. Clutch pressure arm and movable pressure ramp
2. Clutch pressure balls
3. Fixed clutch pressure ramp
4. Bearing retainer plate
5. Fan
6. Starter ring gear
7. Clutch drive drum
8. Clutch driven drum
9. Roller bearing
10. Clutch output flange and splined stub shaft
11. Clutch plate, drive
12. Clutch plate, driven
13. Pressure plate
14. Clutch pressure springs
15. Pressure release plate and bearing retainer
16. Ball bearing

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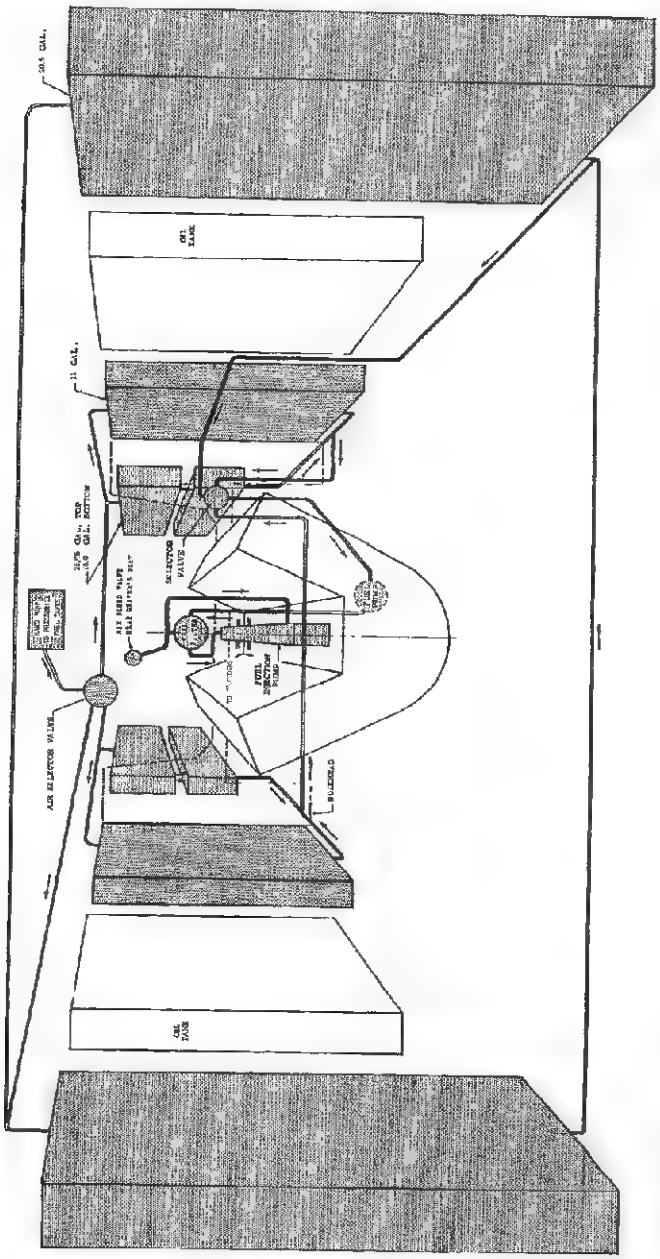

0300 - ENGINE FUEL SYSTEM
LOOKING FORWARD FROM REAR OF TANK

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FUEL SYSTEM - INJECTOR PUMP

This 12-cylinder fuel injection pump is a conventional German type and is described as a "PE 12B-100" injection pump with ball-type governor. The purpose of the injection pump is to deliver, under high pressure, a metered volume of fuel oil to the cylinder at the precise time for most efficient combustion. The amount of fuel to be delivered is regulated through small valves in the pump by the ball-type governor attached to the rear of the injection pump.

25X1B

The pump appears to be fairly well made and, although inferior to U. S. products in general overall quality and appearance, entirely adequate for the application. The pump examined [redacted] was comparable to an American made pump after approximately 3500 hours of service. It was estimated that the life of this pump would be 1000 hours.

The camshaft was supported by two ball bearings (one at each end) and five two-piece aluminum bearings uniformly spaced along the camshaft with two cam lobes between bearings. This is a more rigid support than is usual in U. S. practice. The tappet rollers had needle bearings. U. S. practice is to use a loose steel sleeve-type bearing between the tappet pin and the tappet rollers. A desirable feature found on this pump and not common on U. S. pumps is the provision in the design of the control sleeves to permit the removal of the plunger from the top of the pump. Fuel is fed into both ends of the pump to insure adequate supply to all cylinders. The rear fuel supply line is also connected to an air bleed valve to remove air entrapped in the fuel system. Fuel leakage past the nozzle valves and plungers is drained into the crankcase where it mixes with the engine lubrication oil. Lubrication of the pump after installation (before leakage provides fuel oil lubrication) is evidently provided by pouring a small amount of oil into the camshaft compartment. An oil level dipstick was provided on the pump to check for the presence of this oil before the engine was first started. Apparently, this dipstick was never used after the first oil supply was established. The dipstick location was not the same on the two G812 pumps (see photographs).

The body of the pump and the five camshaft bearings were made of an aluminum alloy. Rubber gaskets were used to seal the delivery valve fittings. All other parts were of steel.

The pump body was cast using the permanent mold with sand core process. Steel parts were machined all over and wearing surfaces appeared to be well ground. Tolerances were at the high limit of U. S. standards, but were considered satisfactory. [redacted]

25X1B

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Removal of intake manifolds and fuel injection lines would be necessary for servicing of the pump. The pump is fastened to the three cast iron brackets by six long thin bolts. The cast iron brackets were bolted to the upper crankcase. The long bolts were probably used to permit rocking of the pump to align it more perfectly with the air starter shaft and thus to minimize load on the phenolic laminate driving disc.

More details on performance and dimensions are available in a separate report in the appendix. Photographs of the pump parts may also be found in the appendix.

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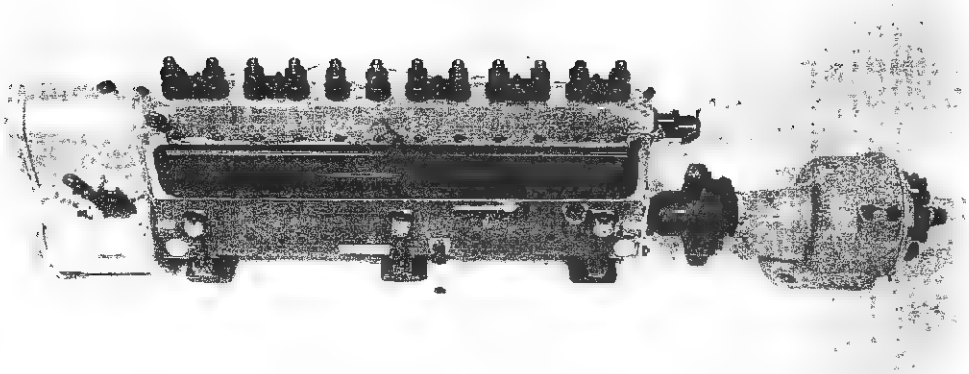

0301,1 - FUEL INJECTOR PUMP - ENGINE 25X1B [redacted]

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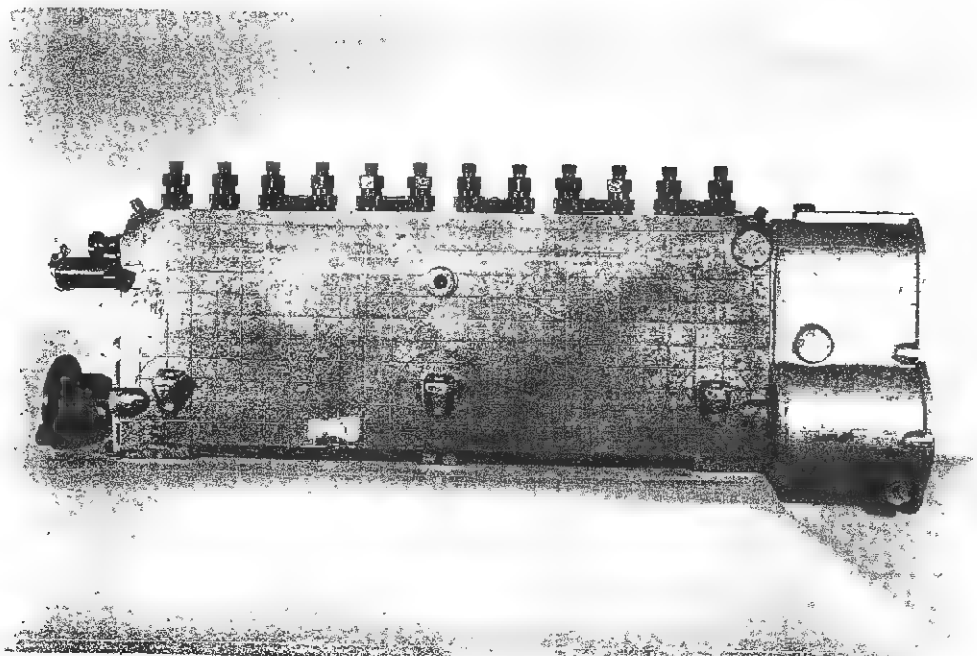

0301.1 a - FUEL INJECTOR PUMP - RIGHT SIDE - ENGINE [redacted]

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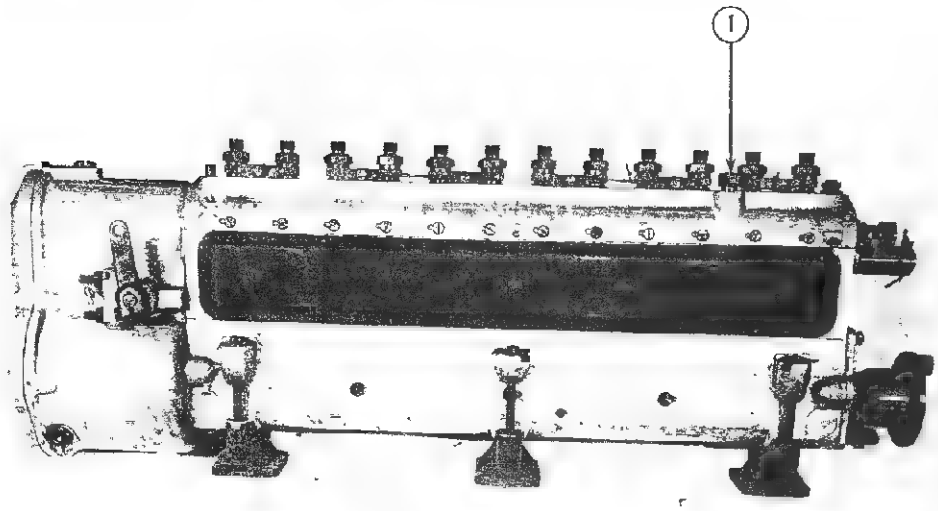

0301.1 b - FUEL INJECTOR PUMP - LEFT SIDE - ENGINE 25X1B [redacted]

1. Oil level dipstick

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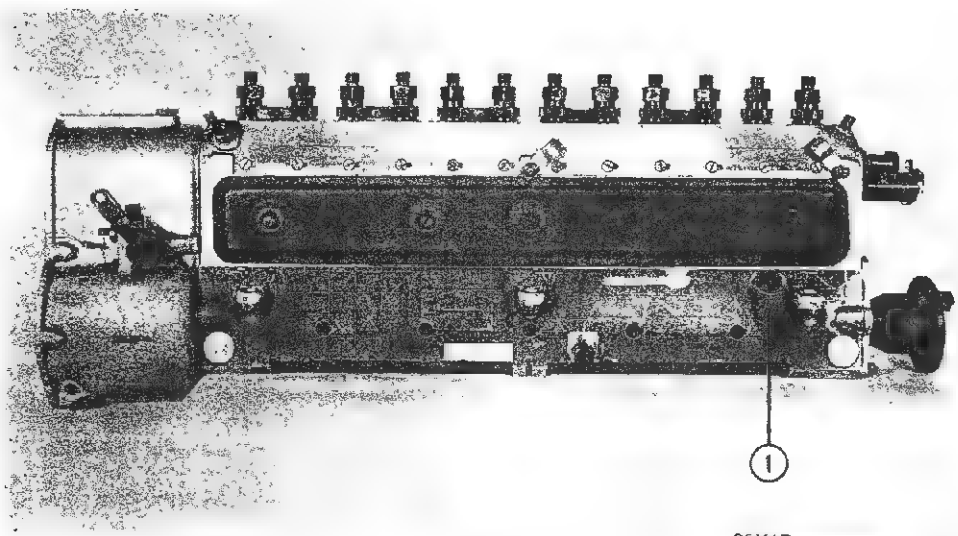

0301.1 c FUEL INJECTOR PUMP - LEFT SIDE - ENGINE 25X1B [redacted]

1. Oil level dipstick

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0301.3 - FUEL INJECTOR PUMP ASSEMBLY - ENGINE [redacted]

1. Pump mounting bolts
2. Lock for pump mounting bolts
3. Pump mounting bracket
4. Inspection plate
5. Closing plug with felt cushion
6. Tappet assembly
7. Plunger, barrel, and spring assemblies
8. Barrel set screw
9. Bearing set screw and washer
10. Fuel inlets from filter
11. Barrel set screw
12. Screw for delivery valve body lock
13. Washer for delivery valve body lock
14. Delivery valve body lock
15. Delivery valve assembly
16. Pump body
17. Fuel rack
18. Fuel rack stop
19. Coupling
20. Camshaft nut and washer
21. Coupling key
22. Camshaft and camshaft bearing assembly
23. Ball bearing with oil thrower
24. End plate
25. Oil depth gauge

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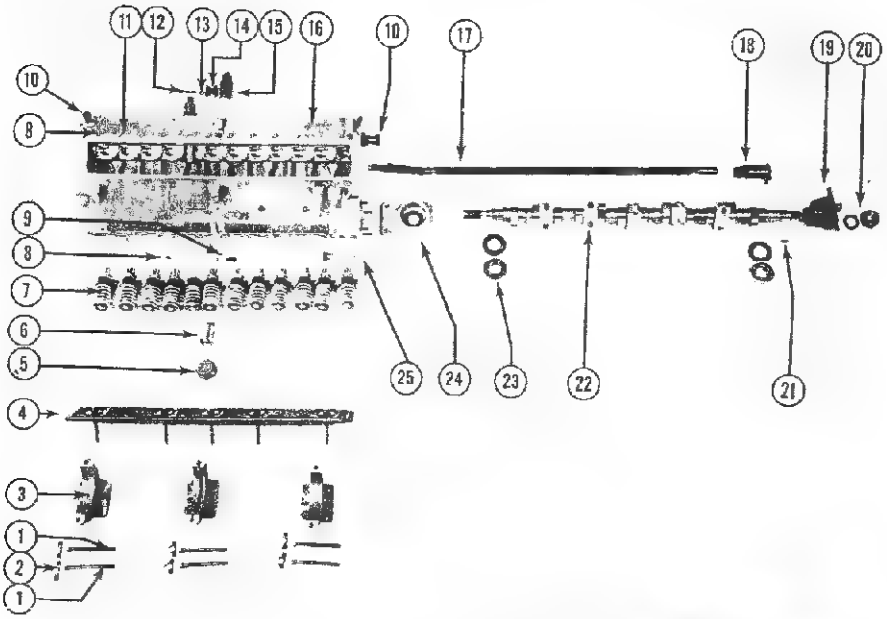

0301.3 - FUEL INJECTOR PUMP ASSEMBLY - ENGINE 25X1B [redacted]

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FUEL SYSTEM - FUEL TRANSFER PUMP

This pump is provided to supply fuel to the fuel injection pump at essentially constant pressure. An internal pressure relief valve permits fuel to recirculate within the pump when control pressure is reached. On its way from this pump to the injection pump, the fuel passes through the fuel filter, with consequent loss of some of the pressure imparted.

This pump was found to be very similar to the Pesco vane-type pump made in the U. S. and shown with it in the photograph on the next page.

The pump body was sand cast aluminum. The vanes, spider and barrel were hardened steel. Bearings were copper alloy bushings. The ground finishes on the steel parts and overall quality of the pump were excellent. No signs of wear were found.

This pump was different from the pump pictured in the German report, although the latter was also of the vane-type construction.

[redacted]

25X1B

[redacted]

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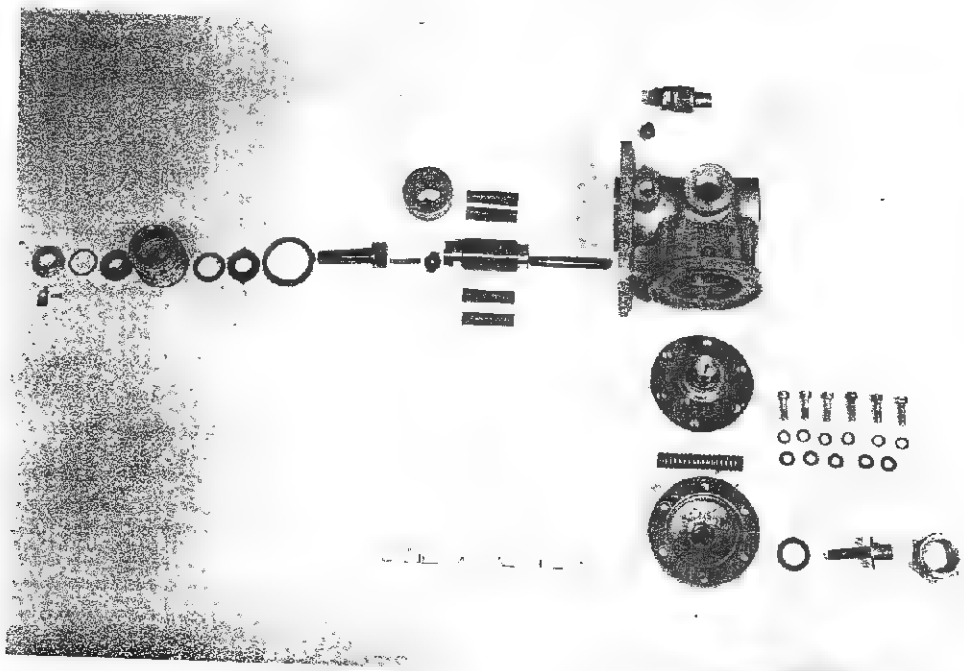

0302.1 - FUEL TRANSFER PUMP ASSEMBLY - ENGINE [redacted]

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AIR CLEANERS

Two tractor-type air cleaners were used on the G812 tank. They replaced the old hat-type cleaner which was formerly mounted on top of the engine.

The air cleaners were made in three parts. The bottom section was merely a large empty can and was intended to collect dirt removed by the upper sections. There was very little dirt in this part when received. The middle section consisted of a cylindrical sheet metal container with seven centrifugal dirt separator cones welded inside. The purpose of the cones was to make the incoming air assume a helical path and, by centrifugal force, separate the dirt from the air. (Experience with this type of dirt separator on automobiles has shown it to be almost worthless.) The upper cleaner section consisted of oil wetted wire mats. The three sections were fastened together with bolts. The two cleaners were individually connected to the two intake manifolds, with no interconnection between them.

The air cleaner body was made of sheet metal which had been drawn to shape and welded. It was well made.

To service the air cleaners, at least one transverse louver would have to be removed from the top of the hull. This required removal of four bolts from one of the end plates which provided sockets for the louver trunnions. Because of the poor accessibility of the air cleaners, it is unlikely that they were serviced very often. The cleaners were of such low efficiency and low dirt capacity that, in dusty operation, they should have been cleaned at least once each day and preferably several times if any appreciable engine protection were to be obtained.

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0304 - INTAKE AIR CLEANER

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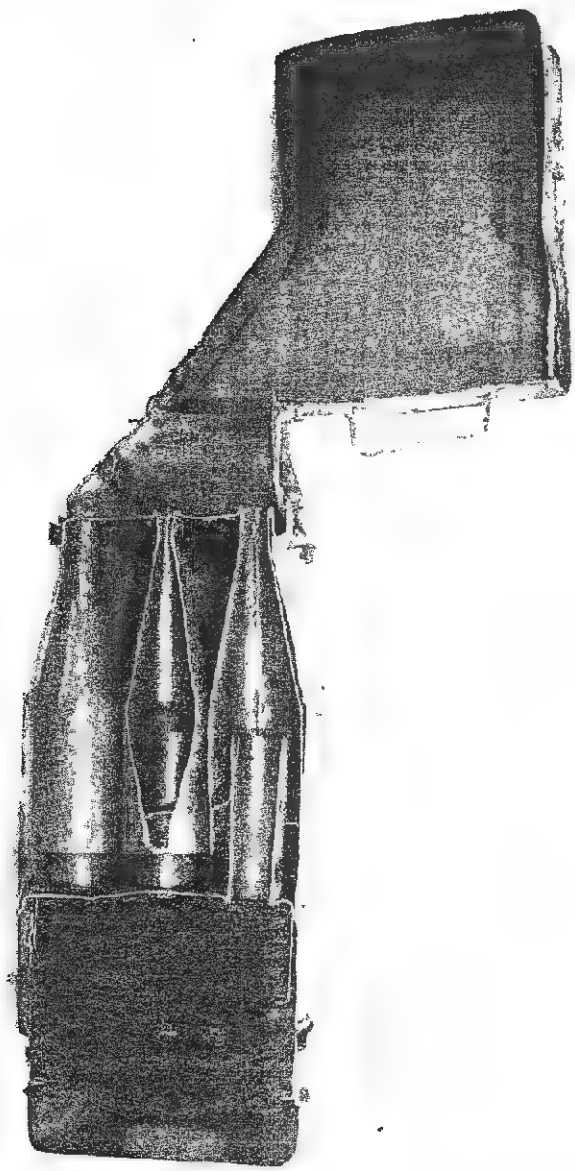

0304.1 - INTAKE AIR CLEANER - SECTION VIEW

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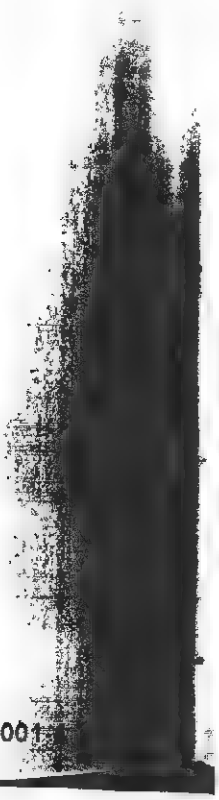
ELBOW, AIR INTAKE SYSTEM

This casting appears to be one of the few parts on the tank, which is over-complicated in design. Fins are cast integrally with the body and are valueless in function. They were probably intended to minimize air turbulence in the necessary right-angle bend, but are on the wrong bend and in the wrong direction to do any good. A small steel plate bolts to the bottom of the casting to cover openings, which were used to support the core during casting.

The elbow is an aluminum alloy sand casting with rough surface appearance and good overall soundness.

Intake manifolds and air cleaner ducts are fastened to the elbow by hose connectors.



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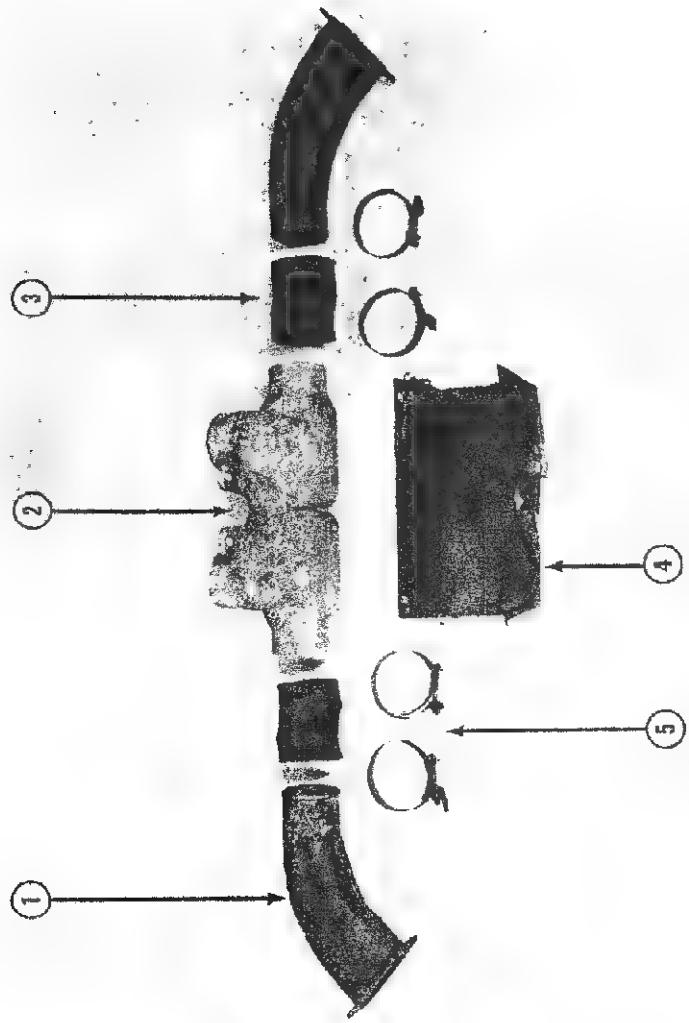

0304.3 - AIR CLEANER TO INTAKE MANIFOLD DUCT ASSEMBLY

1. Air duct
2. Intake air elbow
3. Elbow-to-air-duct connection hose
4. Steel sheet with asbestos-like material to insulate elbow
5. Hose clamps

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FUEL AND OIL TANKS

The G812 tank had eight fuel tanks of 147 gallons total capacity and two lubricating oil tanks of 35 gallons total oil capacity. The Aberdeen report mentioned six fuel tanks of 120 gallons total capacity. The Aberdeen report photographs show tanks similar to those in the G812 tank, except that they appear to be made using less preforming of the steel before welding.

All tanks appear to be well and carefully made. All fuel and oil tank filler openings were equipped with a 40 mesh brass cloth cylindrical strainer. All fuel tanks had drain plugs with corresponding plugs in the hull bottom for complete draining of the fuel. The oil tanks had valves for draining. The tanks, both fuel and oil, are filled by removing small armor plates bolted over the filler opening caps. The oil tank filler opening caps were also pressure relief caps. Their purpose could be to prevent escape of oil when the tank was tipped sidewise or of oil foam when the tank is moving over rough ground. The oil tanks were vented to each other and to the engine crankcase, which was vented to atmosphere through a breather tube with a crumpled wire filter in the breather tube.

All tanks were made of drawn steel sheet, welded at the seams. They appeared strong and had no leaks.

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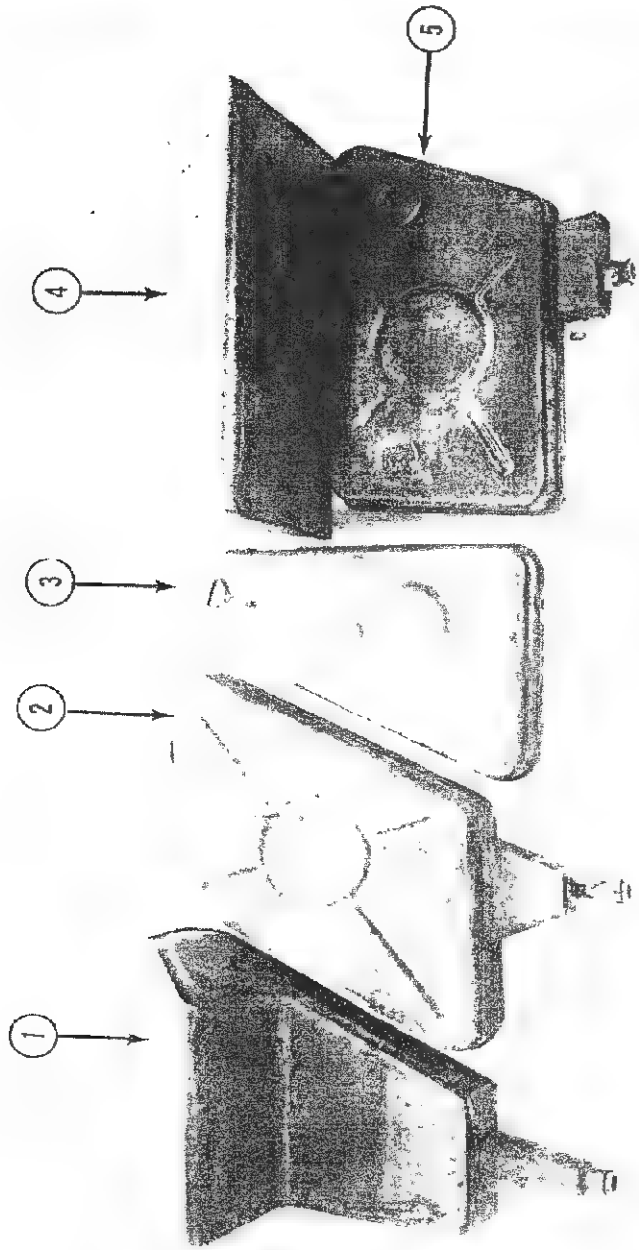

0306.1 - FUEL AND LUBRICATING OIL TANKS

1. Rear fuel tank, 20.5 gallons capacity
2. Oil tank, 17.5 gallons capacity
3. Engine compartment fuel tank, 11.0 gallons capacity
4. Fighting compartment upper fuel tank, 25.75 gallons capacity
5. Fighting compartment lower fuel tank, 16.0 gallons capacity

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FUEL INJECTION PUMP GOVERNOR

This ball type governor is similar to the Novi governor used on the Ford V8 tank engine, except that it is direct acting on the fuel injection pump rack which turned all 12 injector valve barrels. No servo mechanism is used. Outward radial movement of the balls in respect to centrifugal force causes axial force on the cone faced plate and the opposing flat plate. The flat plate, being free to slide (except for spring resistance) moves the operating arm which in turn works on the injection pump control rack. The engine speed is controlled by manually changing the tension of the springs which resist axial movement of the flat plate.

All interior parts were smoothly machined and in good condition. Wear on the pressure plates had occurred to a slight degree. A ball thrust bearing is used to transmit axial thrust and a needle bearing is used on the control arm. The governor case and cover plate were permanent mold, aluminum alloy castings.

25X1B

25X1B

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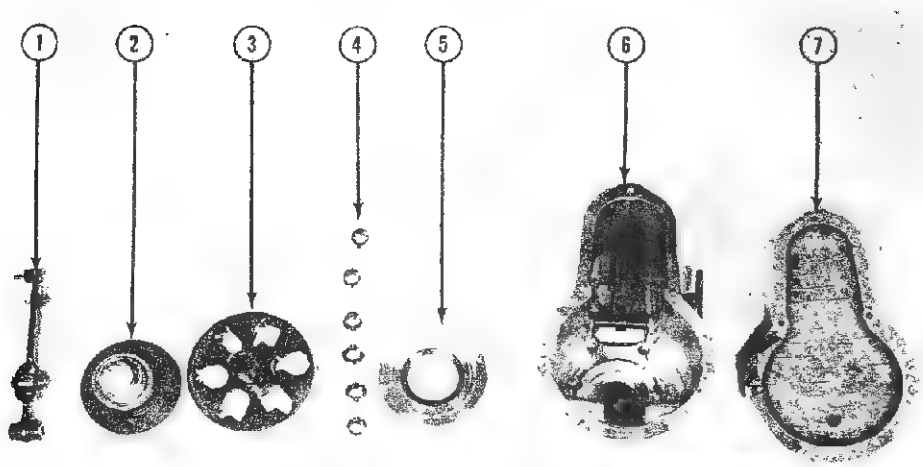

0308 - GOVERNOR ASSEMBLY - ENGINE [redacted] 25X1B

1. Fuel injector pump control arm - needle bearing roller presses against flat pressure plate to restrain axial movement
2. Flat pressure plate - with ball thrust bearing - rotated by balls, moved axially as balls fly out
3. Ball weight guide plate - steel, keyed to injection pump shaft, drives balls
4. Ball weights
5. Conical pressure plate
6. Governor body - permanent mold aluminum casting. Tension springs connect to control arm
7. Cover plate - permanent mold aluminum casting, possibly die casting

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FUEL FILTER

The fuel filter consisted of a tubular metal sieve, used as a core for a stack of square felt pads. The fuel was thus required to travel radially through one-half to one inch of felt before reaching the perforated core. This type of filter appears vulnerable to early plugging. Five mesh screens were provided on the fuel tank openings to prevent large pieces of dirt from entering the fuel system.

An air bleed connection was provided on the output side of the filter to remove entrapped air. A line leading to a valve near the driver's seat was fastened to this connection.

This filter is apparently similar to that used on the Aberdeen and German tanks. The German report describes it as being a copy of the Bosch filter.

The filter is readily accessible for servicing.

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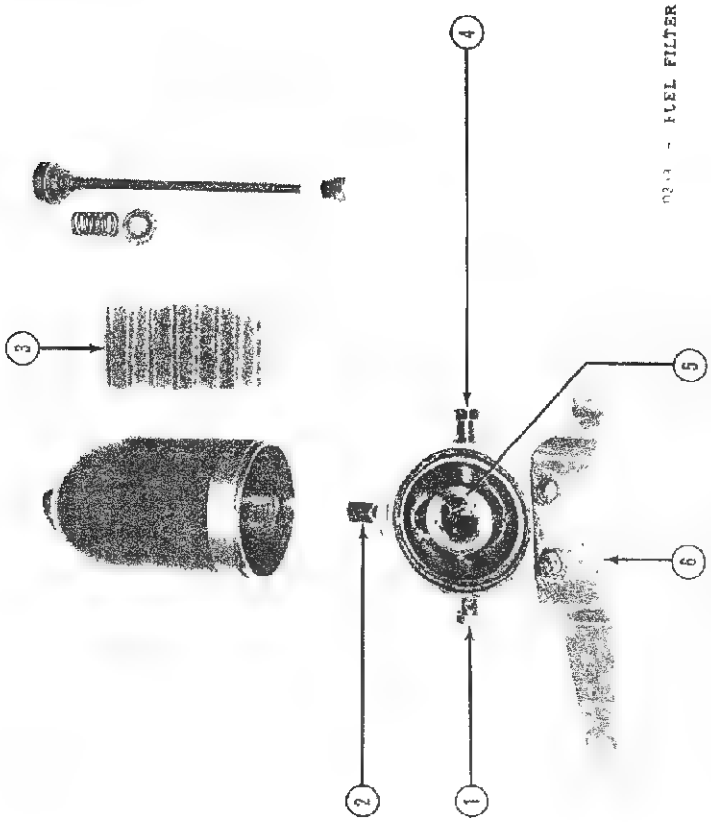

0309 - FUEL FILTER

1. Inlet from fuel transfer pump
2. Outlet to rear fuel injector pump connection and to air bleed valve
3. Filter element
4. Outlet to front fuel injector pump connection
5. Felt seal

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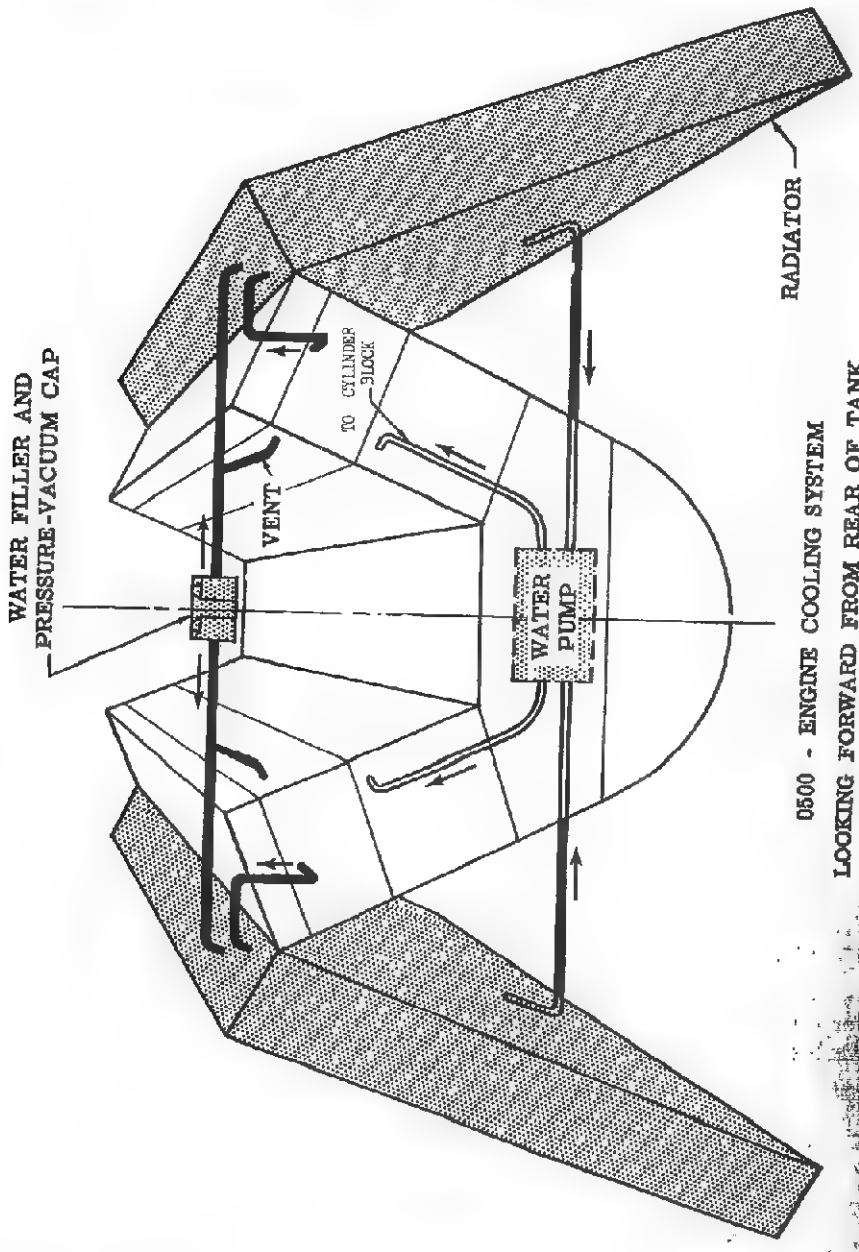

0500 - ENGINE COOLING SYSTEM
LOOKING FORWARD FROM REAR OF TANK

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WATER RADIATORS

According to the Aberdeen report, considerable trouble was experienced in proper cooling of the engine. The report said that if the tank were operated in an ambient temperature of 70° or over, the cooling would not be satisfactory because of boiling of the water.

The G812 tank demonstrated some possible causes of the poor cooling in the Aberdeen tank. Tube and fin construction of the radiators was very poor, particularly the soldering of the fins to the tubes. It was estimated that over 90% of the fins were non-functional, either for heat dissipation or core support because of the poor contact area of fins to tubes. There was no oil radiator in the Aberdeen tank, as there was in the G812. The addition of the oil radiator would help solve the cooling problem and may represent a change in design for that purpose. There was no way to tell if a change in the size of the fan had been made since the Aberdeen report, but the fan in the G812 tank may be bigger than that described in the German report (dimensions in the German report are too vague to be sure of a change).

25X1B

25X1B Each water radiator was made of four parts, two of them being of two-tube thickness and the other two of three-tube thickness. [redacted]

Water radiators were very close to the exhaust manifold. Areas close to the exhaust manifolds were not different in appearance however; the poorly soldered tube-to-fin connections were the rule, rather than confined to this area.

Area of the water radiator was approximately 1600 square inches. Capacity of each radiator was 7-1/2 gallons.

25X1A The following report, [redacted] furnishes more details on radiator construction.

SECTION OF RADIATOR CORE REMOVED FROM RUSSIAN TANK

The construction of this fin and tube type core was very poor, indicating that the radiator was either made from very poor tools, or was made without extensive use of tools. The selection of materials for the core was inconsistant in that one section had brass fins and the other copper. In general, it appeared that the radiator was made from available equipment and material, rather than designed for the specific application. There was no apparent attempt to conserve on the amount of solder used, however, this may have been necessitated to some extent by the poor tooling setup.

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The core depth was approximately 3-15/16", consisting of two adjacent parallel cores; one section having a 2-3/8" copper fin, three tubes deep; and the other a 1-9/16" brass fin, two tubes deep; all fins had poorly formed rolled edges. The fin spacing was approximately 6-3/8 fins per inch. Several reasons can be advanced for the divided construction of the core; such as,

1. Lack of die of sufficient depth.
2. Addition of a second section to gain necessary cooling.
3. An attempt to prevent curvature or disfiguration of core when installing the tubes.

The distance from the last tube in each row to the ends of the fin varied from 1/2" to 2". The angle of cutoff varied, which indicates that the fin die was not equipped with an automatic cutoff and that the strips of fin material were snipped apart by hand. It also suggests that the core may have been assembled by applying the fins to the tubes individually, rather than inserting the tubes into the fins.

Tubes were made of flattened seamless tubing with a wall thickness of .011", including solder coating. Tubes were located on 1/2" centerlines and 60^0 angle to core face. Cross-sectioned tubes measured approximately .665 x .145". The openings in the fins exceeded the .145" dimension by several thousandths throughout the core section. This condition resulted in only an occasional point of contact between the fins and tubes. As the result, over 90% of the entire fin area was non-functional, either for heat conduction and dissipation, or necessary core strength. The flanged openings were crudely formed as far as any intended fit to the tube contour. The dies used in forming the fins can be presumed to be very crude, particularly in regard to shape of punches.

The last tubes in each row were plugged with solder at the header. This condition can prevent failure of the tubes due to stress, these points being the most susceptible. However, it does not remedy tube to header solder joint failures. A tube to header solder joint failure was noted at the leading edge of one plugged tube at the end of the outside row. The .032" header thickness is very light for an assembly using bolted on tanks.

25X1A Shown below is an analysis of the Russian Tank radiator as compared with the standard material used for [redacted] fin and tube radiators.

Material	Cu.		Sn.		Pb.		Zn.	
	Russ. Tank	[redacted]	Russ. Tank	[redacted]	Russ. Tank	[redacted]	Russ. Tank	[redacted]
Header Brass (.032)	62.9	66.	-	-	-	-	Bal.	Bal.
Tube Brass (.011)	96.9	85.	-	-	-	-	Bal.	Bal.
Fin Brass (.005)	62.9	-	-	-	-	-	Bal.	-
Fin Copper (.006)	100.	100.	-	-	-	-	-	-
Header Solder	-	-	38.2	30.	Bal.	Bal.	-	-
Tube Solder	-	-	25.6	30.	Bal.	Bal.	-	-

25X1A 25X1A 25X1A 25X1A

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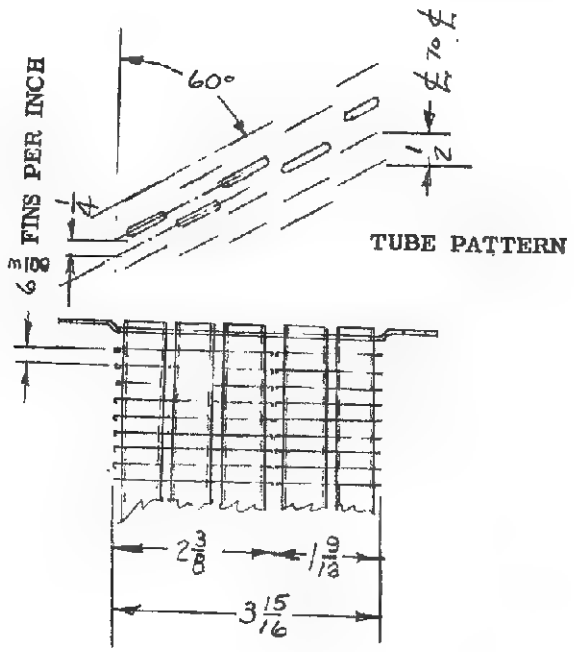
SECTION OF THE G812 RADIATOR CORE



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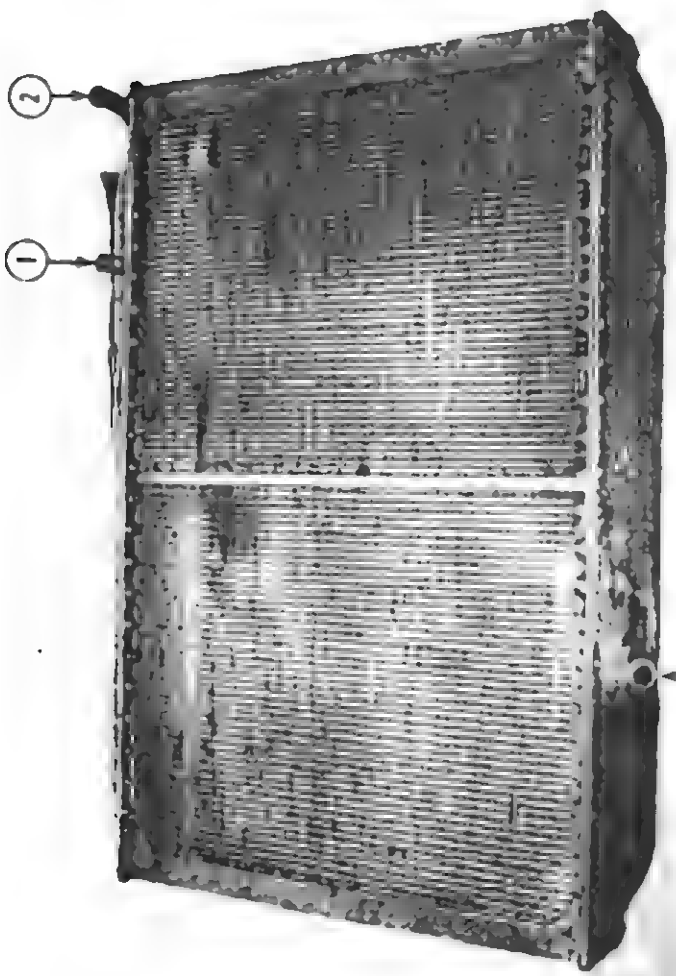

0501.1 - RIGHT WATER RADIATOR

1. Connection to filler and pressure-vacuum cap assembly
2. Connection to head
3. Connection to water pump inlet

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COOLING SYSTEM - WATER PUMP

The water pump in the G812 tank was the same centrifugal type mentioned in the German and Aberdeen reports, with minor changes. The pump impeller in the G812 tank was an aluminum alloy, permanent mold casting. The German report mentioned a bronze impeller.

The bearing packings were different on the G812 tank also. The German report showed a seal with two packings, one to seal against water and the other against crankcase oil; whereas the G812 pump had three seals with the grease input from a reservoir between the bottom two seals. The German pump apparently had a grease fitting leading to the center of the brass bushing. This would tend to introduce grease into the cooling water.

The Aberdeen report mentioned water pump shaft and coupling failures. Perhaps the above changes were made to help prevent more failures.

The water pump housing was cast iron with fairly good surface qualities. The impeller was supported by one copper alloy bushing and one ball bearing (17 mm ID, 47 mm OD, 17 mm wide).

The pump was coupled directly to the lower accessory drive shaft and operated at 1.5 engine speed.

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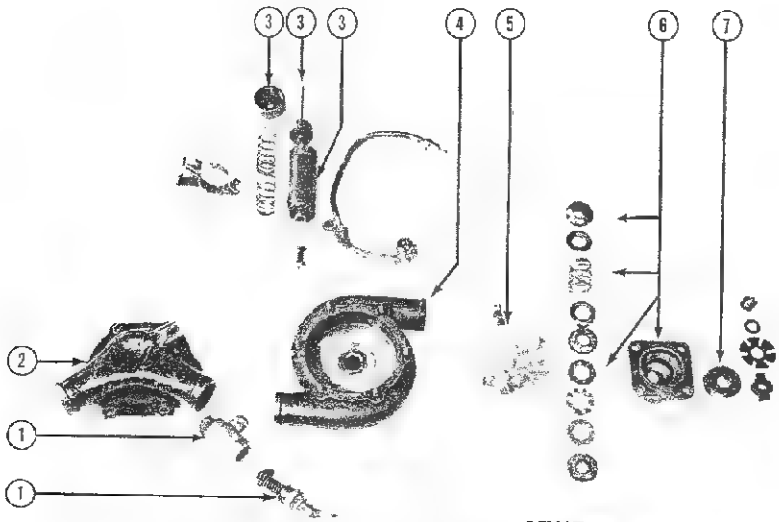

25X1B

0504.1 b - WATER PUMP - ENGINE [redacted]

1. Water system drain valve assembly
2. Pump body, inlet side
3. Pump bearing lubrication assembly
4. Pump body outlet side
5. Pump impeller
6. Water and oil seal assembly
7. Ball bearing

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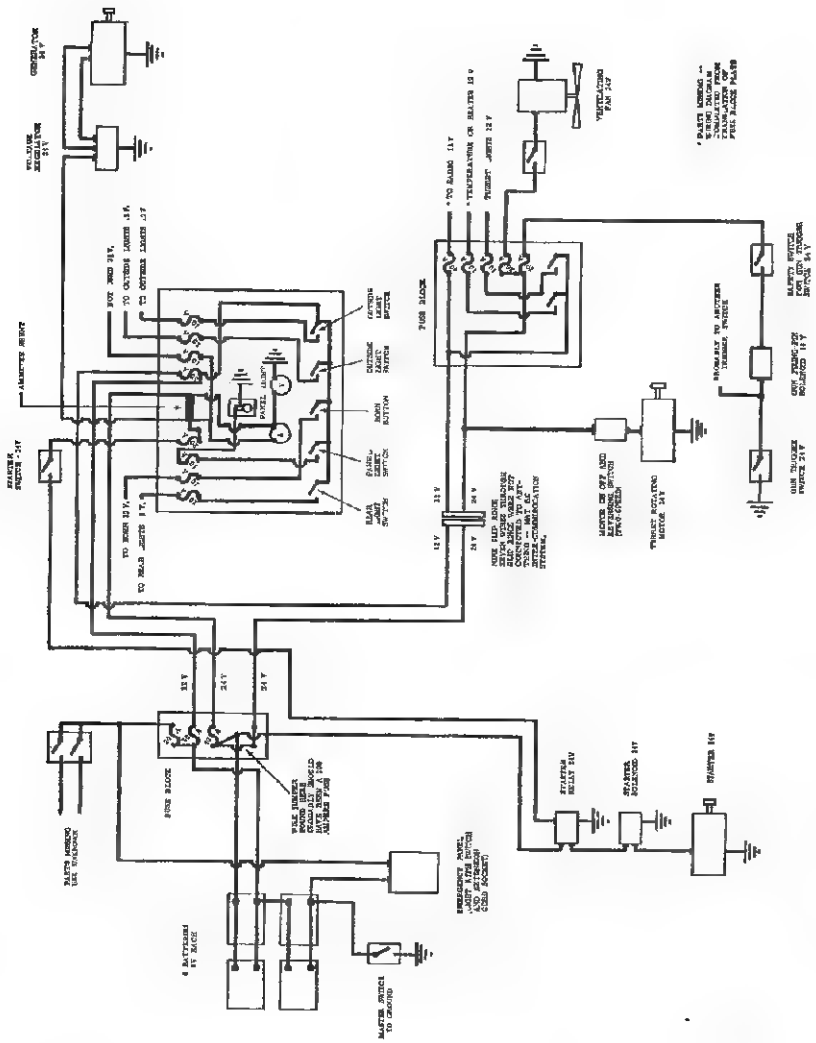

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GENERATORS

Both generators - one from each of the two engines - were found to be totally enclosed. The generator from the '48 engine differed from the earlier model primarily in having three cooling fans. The earlier generator had none. This effort to increase generator capacity was understandable in view of the absence of any auxiliary power plant. Current capacity was not measured, but it was judged to be about 75 amperes for the fan-cooled model. This estimate agreed with the 75-0-75 range of the ammeter on the instrument panel.

The fans used on the later generator were all radial-type. One was located inside the generator at the anti-commutator end, and served to circulate the enclosed air. The other two were on the outside, at opposite ends, and forced air over the respective end bells. The fan at the front was apparently intended to direct air radially outward, but it seemed that little cooling would be so obtained since the blades of the fan were virtually shielded from the generator by the connecting web forming part of the fan structure. The fan at the rear of the generator was baffled so as to cause air to be drawn inward toward the fan eye while passing over the end bell. This fan was probably more effective. It is not understood why the attempt was made to have air circulation inward at one end and outward at the other.

Both generators were of conventional four brush design. The newer was found to have a greater number of armature poles and commutator segments, perhaps to minimize radio interference as well as to increase efficiency.

Both generators were found to have ball bearings at each end, and used felt shaft seals.

The drive coupling provided on these generators was a resilient type, two axial pins on each of the two mating flanges engaging holes in a rubber disc. The German Report and a picture in the Aberdeen Report indicated a friction clutch such as could slip during high engine acceleration. The generator coupling failure indicated in the Aberdeen Report revealed that failure was probably due to torsional vibration. The rubber coupling might well be expected to help prevent such failure.

25X1B

[redacted]

The steel yokes forming the main structural members of both generators were roughly turned, probably from pipe. The pole pieces were bolted on. The end bells of the '48 generator and one of those on the older machine were permanent mold aluminum castings. The remaining end bell was cast iron. All three fans in the later generator were permanent mold aluminum castings.

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Both generators were found in excellent condition. The commutators, specifically, were smoothly finished and were unburned.

The generator control assembly found in the tank included a cut-out relay and a vibrator-type voltage regulator. No current-limiting regulator was provided. Such a regulator is standard equipment on practically all American vehicles, serving to prevent overloading and possibly burning out the generator when it is made to charge badly run-down batteries.

In the voltage regulator three heavy turns of wire were wound around the coil in such direction as to modify the regulator action in the direction of current control. These turns were probably added to improve contact life by providing a sharper break, rather than in the hope of obtaining current control.

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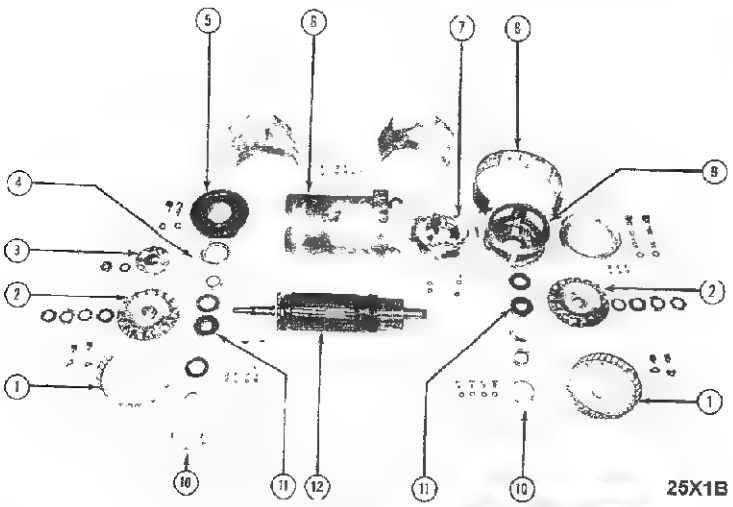

25X1B

0601.1 b - GENERATOR - ENGINE [redacted]

1. Fan guard
2. Fan
3. Generator coupling
4. Bearing retainer and grease seal assembly
5. Head, drive end
6. Yoke and field coil assembly
7. Brush assembly
8. Head cover
9. Head, commutator end
10. Bearing retainer and grease seal assembly
11. Ball bearing
12. Armature assembly with fan

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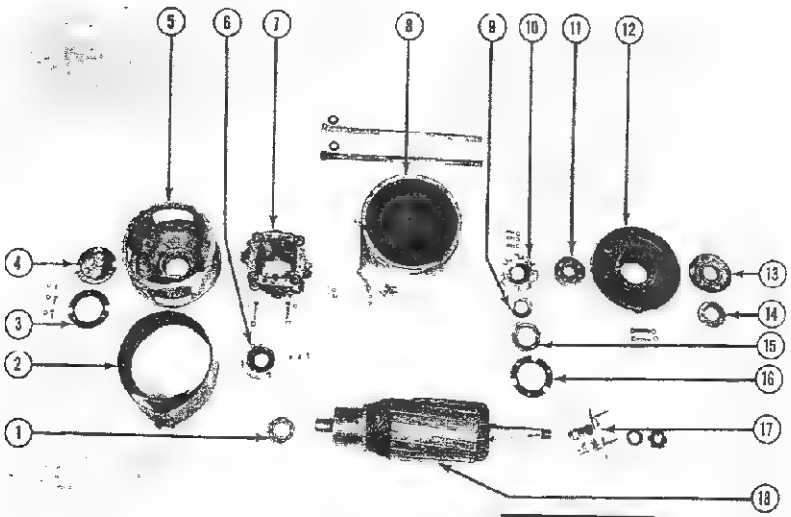

0601.2 a - GENERATOR - ENGINE [redacted] 25X1B

1. Ball bearing
2. Head cover
3. Gasket
4. End plate
5. Head, commutator end
6. Bearing retainer and grease seal
7. Brush assembly
8. Yoke and field coil assembly
9. Felt washer grease seal
10. Felt washer retainer
11. Ball bearing
12. Head, drive end
13. End plate
14. Gasket
15. Grease seal retainer
16. Gasket
17. Generator coupling
18. Armature assembly

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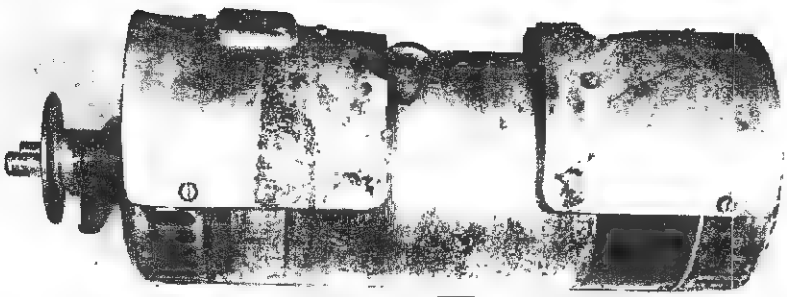
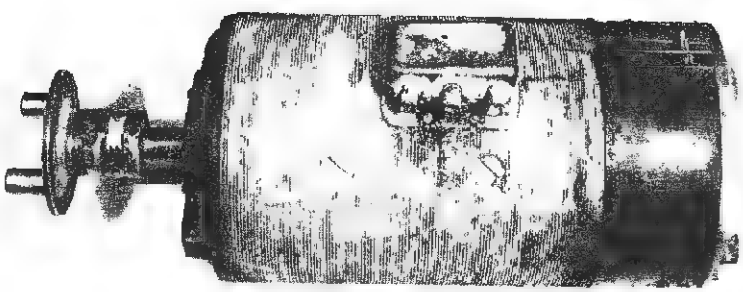


FROM ENGINE [redacted] 25X1B



FROM ENGINE [redacted] 25X1B

0601.3 - GENERATOR COMPARISON

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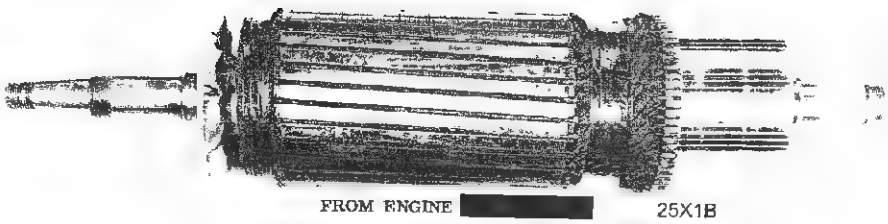
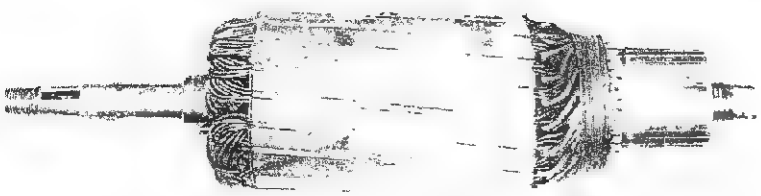


FROM ENGINE [redacted] 25X1B



FROM ENGINE [redacted] 25X1B

0601.4 - GENERATOR ARMATURE COMPARISON

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ELECTRICAL SYSTEM - STARTER

The starter was found to be a conventional four-brush series wound starter motor. It was mounted on the transmission and engaged a ring gear which was bolted to the main clutch and fan assembly. The overrunning clutch and pinion assembly were shifted into positive engagement with the ring gear by means of a solenoid.

The solenoid was of the two-coil type, both coils providing the necessary pull until engagement of the gear teeth was almost complete. The heavy solenoid coil, until then in series with the starter motor, was then short-circuited and the starter pinion and clutch assembly held in engagement by the remaining coil. Current to the starter solenoid and starter was provided by the starter relay, which was held closed as long as the starter switch operated by the driver was depressed.

The clutch, which was added to provide overrunning action so that the engine could not drive the starter motor when it started, was of the multi-disc type. Pressure was applied to the discs by a bushing on the pinion shaft. This bushing was thrust axially by a spiral on the shaft, pressure being obtained when torque was transmitted from the starter armature to the pinion.

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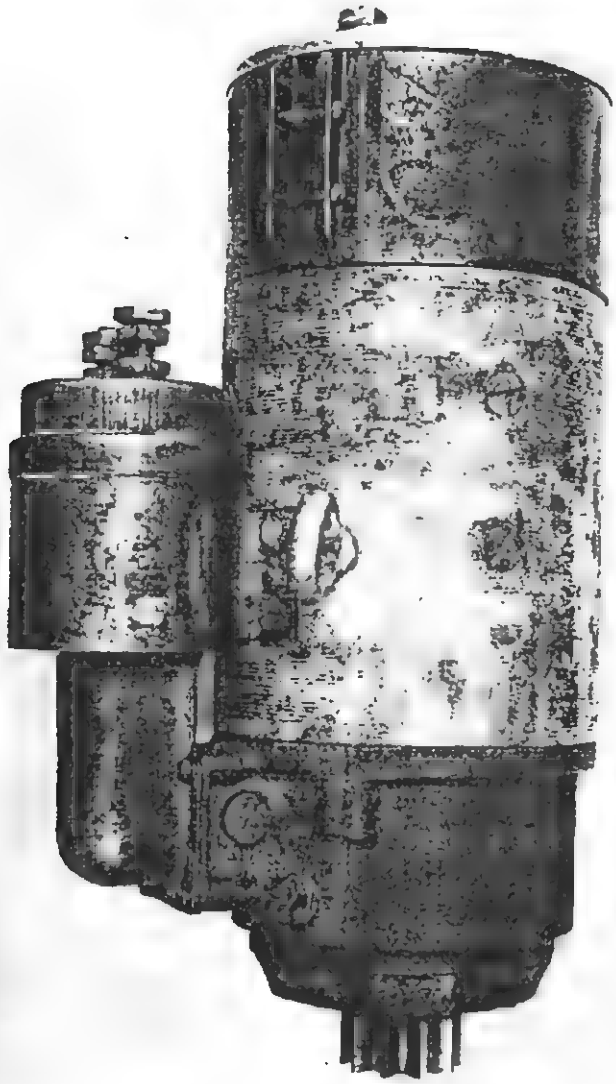

0603.0 - ELECTRIC STARTER

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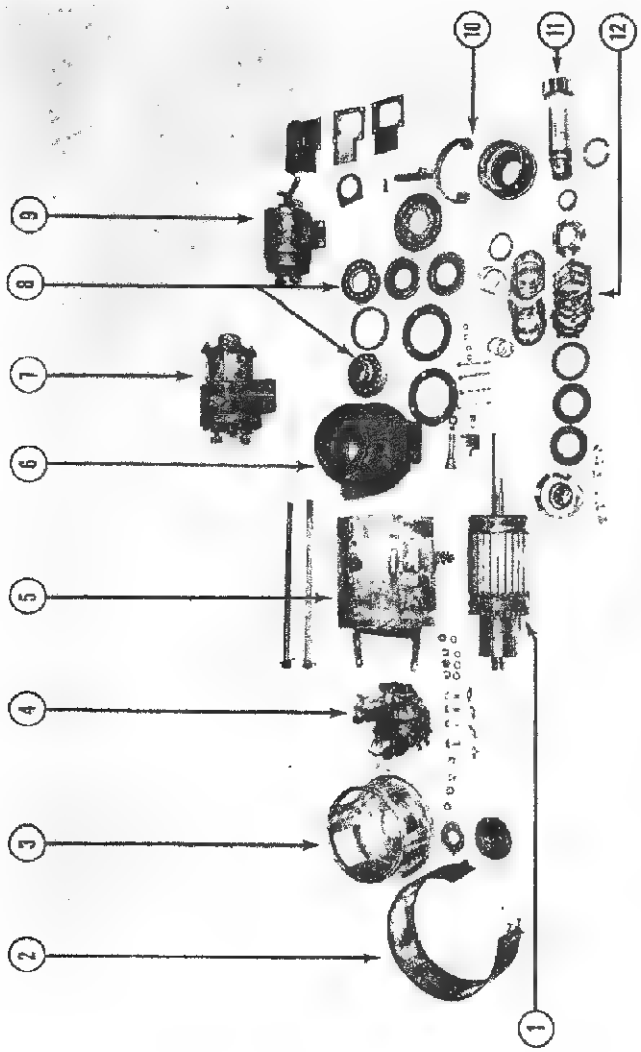

0603.1 - ELECTRIC STARTER

1. Armature assembly
2. Head cover
3. Head, commutator end
4. Brush assembly
5. Yoke and field coil assembly
6. Head, drive end
7. Starter relay
8. Ball bearings, drive end (self-aligning)
9. Solenoid assembly
10. Solenoid-to-clutch pinion linkage
11. Clutch pinion
12. Clutch plates

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ELECTRICAL SYSTEM - STARTER RELAY

This relay appeared to be well made and seemed more than ample for its purpose. The contacts were unplated. Some burning had occurred, but the relay could still be expected to have an adequately long service life.

Only one coil was used for closing and holding the contacts. The main body of the relay was an assembly of two iron castings, a steel tube, and steel end plates.

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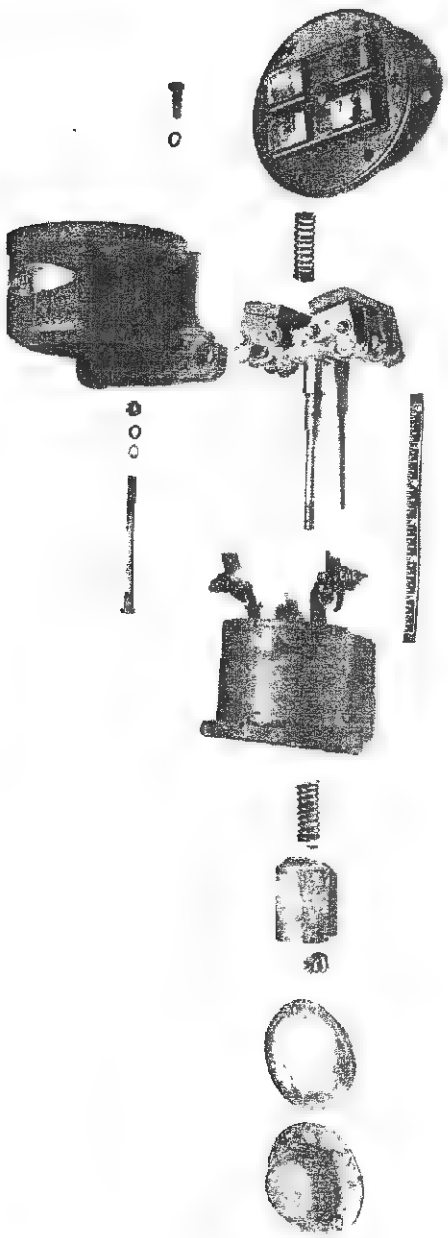

0603.2 a - STARTER RELAY

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MAIN ELECTRICAL CONTROL PANEL

Comparison between photographs of the G812 tank electrical control panel and the photographs showing similar equipment in the Aberdeen report reveals a much more compact and integral design in the G812 tank. All of the loose items shown in the earlier report were combined into a well arranged panel, including the four toggle switches, the horn button, the ammeter and voltmeter, and the fuses. The starter switch, however, had been removed from the panel and moved to a new location near the air starter system control valve. This was apparently done to make possible the simultaneous operation of the air and electric starters.

The voltmeter dial range was 0-35 volts and the ammeter range was 75-0-75 amperes. (Aberdeen reported the ammeter range as 0-50 amperes.) These meters appeared to be of surprisingly high quality for use in a vehicle of any kind. Extremely low friction was combined with adequate damping. External zero adjustment was provided on both meters.

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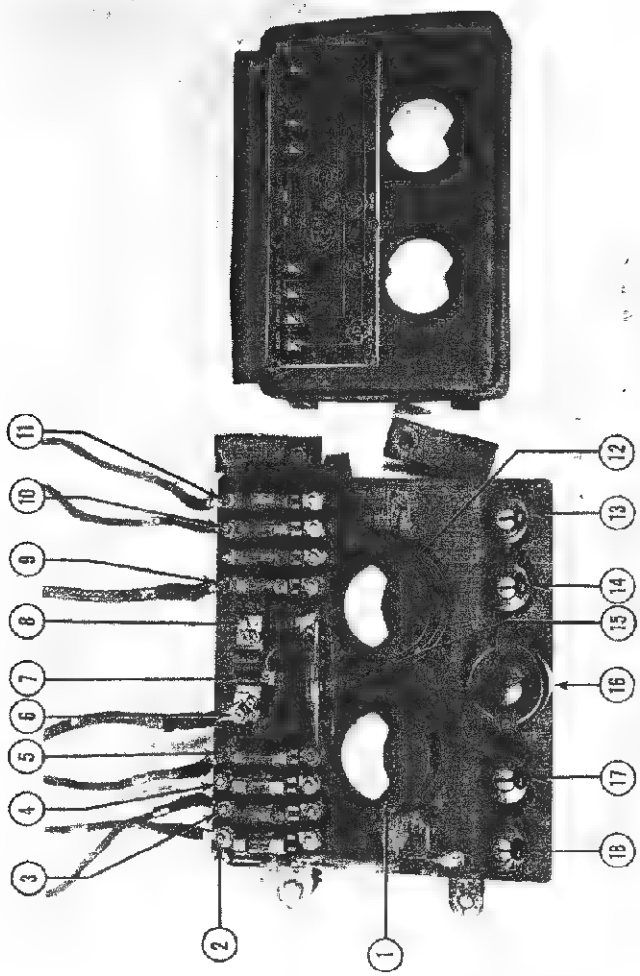

0607 - MAIN ELECTRICAL CONTROL PANEL

1. Ammeter
2. To rear lights
3. To horn
4. To panel light
5. To starter switch
6. To voltage regulator
7. Ammeter shunt
8. Supply, 24 volts
9. Turret supply, 12 volts
10. Outside lights
11. Outside lights
12. Voltmeter
13. Outside light switch
14. Outside light switch
15. Panel light
16. Horn button
17. Panel light switch
18. Rear light switch

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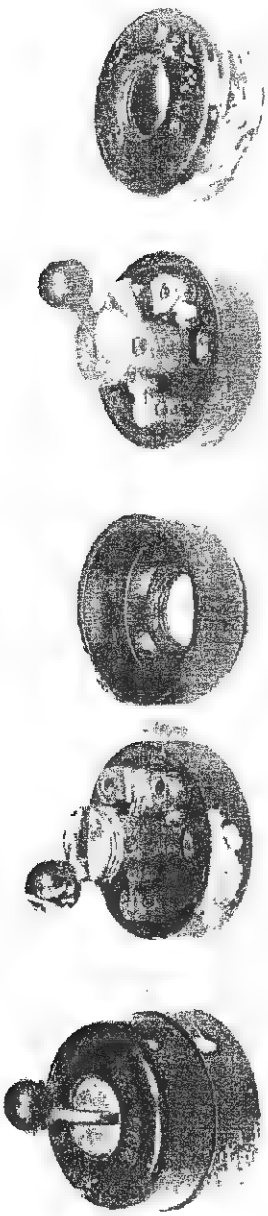

0607.3 - SNAP SWITCH GENERAL PURPOSE

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STORAGE BATTERIES

Four twelve-volt batteries were used in the G812 tank. They were connected in a series - parallel arrangement, so that the voltages available were 12 and 24.

The batteries, as received, contained no electrolyte. The plates were found to be badly sulphated and warped. An attempt was made to return the batteries to a usable condition, but they were ruined beyond the point of recovery. One of the batteries was disassembled for inspection and the following data obtained:

Voltage	12
Mfg. Date	October, 1948
Plates per Cell	17
Positive Plate Size	4-7/16" x 5-11/16" x .180"
Negative Plate Size	4-3/8" x 5-3/8" x .140"
Separator	Wood
Cell Box and Cover	Hard Rubber
Total Weight	136 pounds
One Cell Weight	20.5 pounds
Battery Box	12 pounds
Metal Strap	6 pounds
Overall Dimensions	9-5/16 x 20-5/16 x 9-5/8

The capacity of the batteries was estimated to be 100 ampere hours. This was probably adequate, however, based on our standards for such vehicles. The thick battery plates suggests design for long life. The grids were made of lead with 0.2% antimony added. Common American practice is to use 7 to 12% antimony in the grid to improve life by increasing rigidity and to make easier the ejection of the grid from the mold after casting. The 0.2% antimony in the Russian grids would not be enough to increase rigidity significantly but would help in the ejection process.

The batteries were located on the floor of the engine compartment, on each side of the engine. They were clamped (in pairs) to angle iron bases by hold-down clamps fastened to ears on the battery strap-iron enclosures.

The batteries were not grounded directly to the hull but were connected to a grounded disconnect switch. If a short circuit developed anywhere in the vehicle, the batteries could be completely cut out. An emergency electrical panel (for a light and extension cord) was connected to the 12-volt supply by two wires, so that it could be used when necessary to disconnect the rest of the electrical system.

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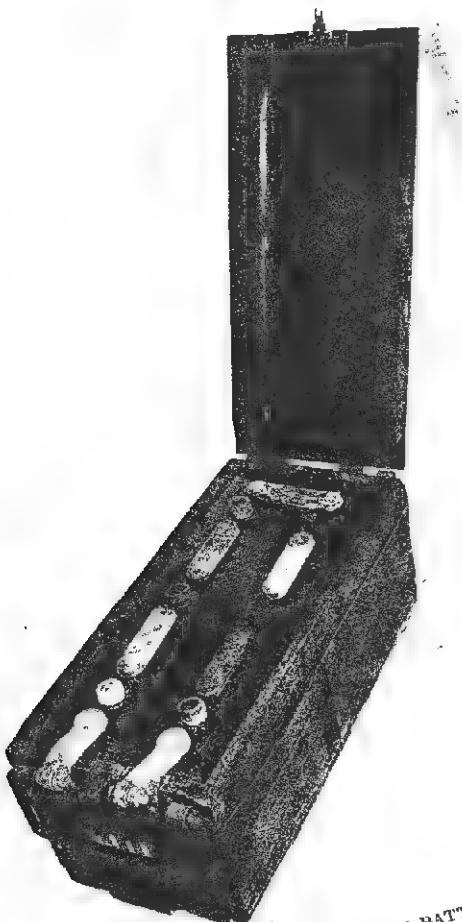

0612.0 b - STORAGE BATTERY

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TURRET ELECTRICAL SUPPLY SLIP RING

This assembly provides a means of connection of 9 wires from the tank hull to the turret. The current supply is necessary to operate the turret traversing mechanism, lights, ventilating fan, radio, and the gun firing system. Only two of the slip rings were used in this particular tank (for 12 and 24 volt supply). The others had been disconnected and were possibly a part of the intercommunication system.

The body of the assembly is made of a rag filled phenolic compression molding stock. Slip rings and connectors are made of silver plated brass. Rivets are used to fasten some of the connectors to the body. The molded inserts in this part are knurled and consistent with U. S. practice.

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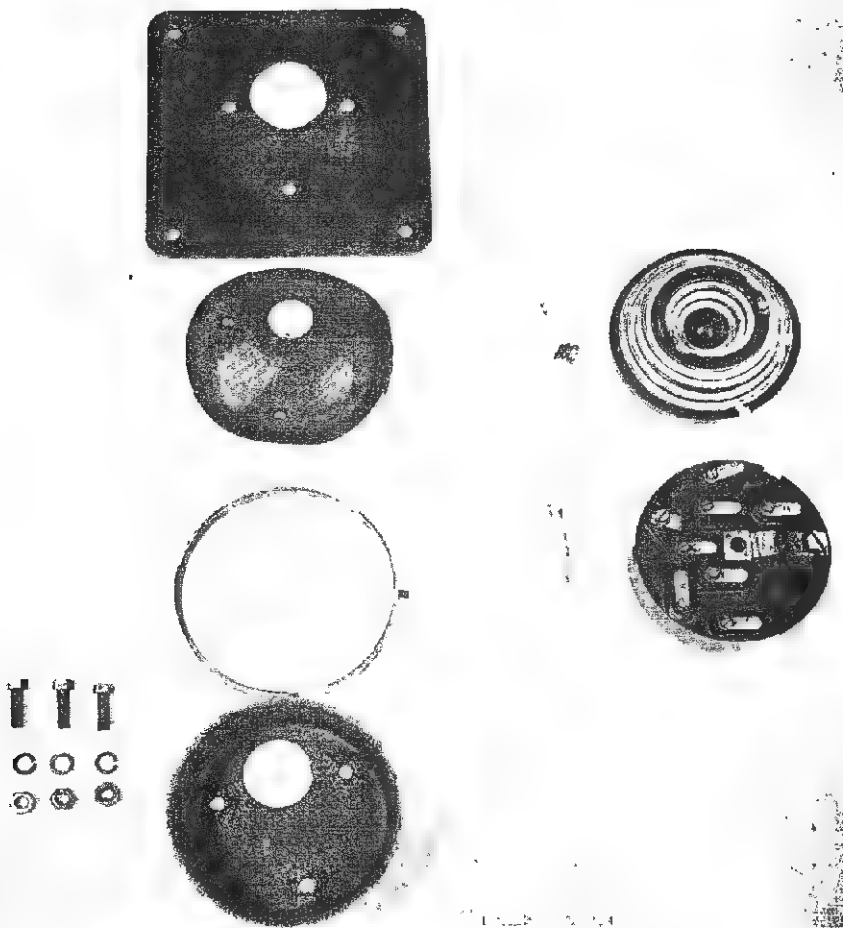

0614 a - TURRET ELECTRICAL SUPPLY SLIP RING

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ELECTRICAL SYSTEM - VENTILATOR FAN

This fan was found to be operated by a shunt-wound 24-volt motor. One pair of the four brushes was grounded, but both field leads were brought out. This would make it easy to change the wiring to reverse the fan motor. It was found to be wired to act as an exhausting fan, driving air from the hull through the ventilator dome in the turret to the outside. Precision ball bearings were provided at both ends of the motor shaft. The bearing at the lower end, carrying fan thrust load as well as the armature weight when the motor was made to operate as an exhaust fan, was a conventional radial bearing which was also being made to serve as a thrust bearing. Its dimensions were 32 mm OD, 12 mm ID, and 10 mm wide.

The bearing at the upper end of the shaft was a ball thrust bearing. This bearing could be made to carry a thrust load only if the motor were made to operate in the opposite direction - to take fresh air in through the ventilator opening. The dimensions of this bearing were 35 mm OD, 15 mm ID, and 8 mm wide.

A toggle switch was mounted on the fan bracket.

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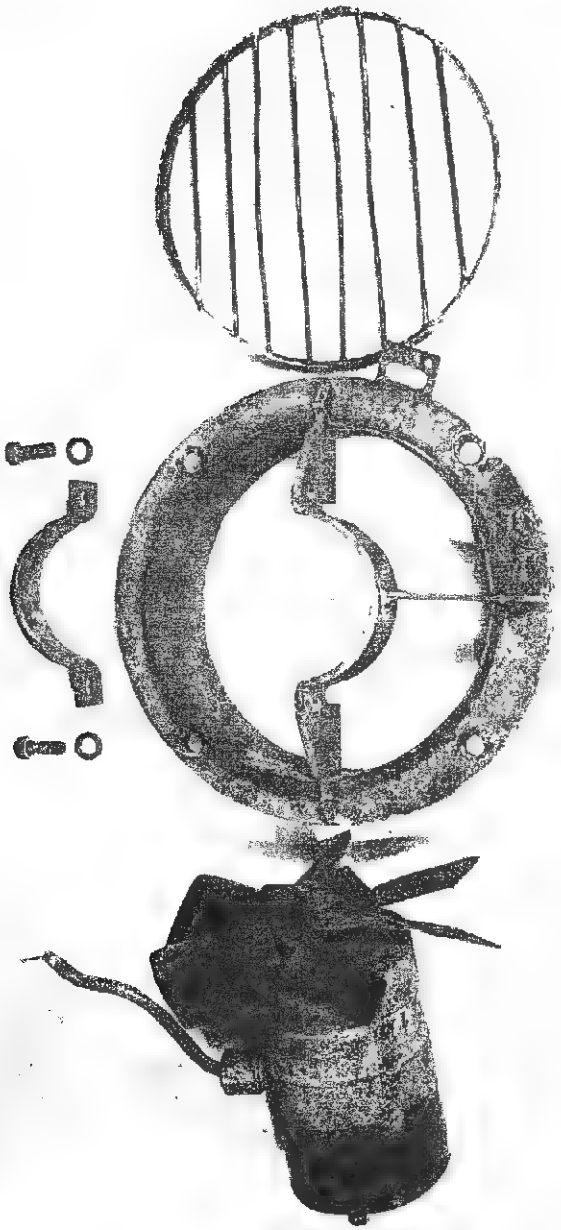

0616 - VENTILATOR FAN AND GUARD

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TRANSMISSION

General

This transmission is a 4 speed spur gear type, with a separate set of gears used for each speed ratio. Speed changing is done by clash-shifting, with no synchronizers provided to assist. Spiral bevel gears at the input provide a cross drive arrangement, with driving gears for all four speeds being mounted on one cross shaft and all four driven gears on another. The final drive pinion shafts are splined to the ends of this driven cross-shaft through the brake-steering-clutch assemblies.

The transmission is supported by a strut at the input pinion boss, and floats on the two final drive shafts.

Gears

The ten spur gears were all finish shaper cut, without any shaving or lapping operations. The spiral bevel gears were much more smoothly finished.

The following are the ratios used:

Spiral bevel input gear ratio = 26/14 = 1.86

Change gear ratios	Overall transmission ratios
1st speed = 35/13 2.69	2.69 x1.86 5.00
2nd speed = 27/21 = 1.29	1.29 x1.86 = 2.39
3rd speed = 21/27 = .777	.777x1.86 = 1.44
4th speed = 14/34 = .412	.412x1.86 = .767
Reverse = 35/15 x 16/13 = 2.87	2.87 x1.86 = 5.33

Note that the third speed gears are now the same diameters as the pair used for second speed, simply being used in reverse order. The T34 tank described in the Aberdeen report had a third speed ratio of .655, provided by gears of 19 and 29 teeth. The new ratio indicated above therefore permitted the elimination of two gear sizes. No advantage was taken of this change for service, however. The respective gears continued to have other differences in form - in the hub length and outside diameter, for example, so that they could not be interchanged in the field. This is especially interesting in view of the probably frequent service replacement of these gears in the field. It would have required only minor casting changes and a small amount of additional machining to have one gear serve as either 2nd speed driven gear or 3rd speed drive gear.

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Further simplification could have been obtained by making the 1st and 4th speed ratios alike (with one the reciprocal of the other). The ratios used - 35/13 and 14/34 represent an unwillingness to change one or the other only 10% to enable obtaining them with the same gear sizes. Thus the opportunity to reduce the number of field service gears and clusters from 6 to 3 was passed over.

The six gears and clusters now used are:

1st and 2nd speed drive gear cluster	13 and 21 teeth
3rd and 4th speed driven gear cluster	21 and 14 teeth
1st speed driven gear	35 teeth
2nd speed driven gear	27
3rd speed drive gear	27
4th speed drive gear	34

The reverse idler cluster has the following gears:

driven - 16 teeth
drive - 15 teeth

Shifting is done by sliding any one of the three clusters along a splined shaft. Three transmission control rods are required. These controls are locked at the driver's shift lever assembly as well as at the transmission itself.

The spiral bevel gear at the transmission input is bolted to the 4th speed drive gear, and this assembly is spaced laterally on the cross-shaft by shims to provide proper alignment for the spiral bevel gear set. Access to these shims requires a major transmission teardown. The mating pinion assembly is also spaced by shims, these being located under the flange of the pinion housing and therefore being accessible from the outside.

Transmission Shafts and Bearings

Thirteen anti-friction bearings are used in this transmission, as follows:

7 straight roller bearings
5 tapered roller
1 ball thrust

Four of the tapered roller bearings take end thrust on the two cross-shafts, there being a pair of bearings at the center of each shaft. Four of the straight roller bearings support the ends of these shafts. Two straight roller bearings carry the reverse idler cluster on its fixed shaft. The three remaining bearings support the input pinion shaft, the tapered roller bearing opposing the ball thrust located at the inner end of the

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pinion shaft, just behind the straight roller bearing that carries the pinion radial load. All thrust bearings were controlled for end play by means of shims. The straight roller bearings carrying the reverse idler were of the Hyatt type, the rolls having been fabricated of spirally wound strip stock and then ground.

In view of the gear failure discussed in detail below, it is interesting to note that the bearings had not suffered any comparable damage, though they may have been loose in comparison with their original condition.

Transmission Case

The case was formed in two halves, upper and lower, which were aluminum sand castings. These castings were rough but there were no blow holes, inclusions or other defects. Many casting fins and scabs and drilling burrs were loosely attached to inside surfaces and could easily be picked off. However, an analysis of the metal fragments found in the oil in the bottom of the transmission case revealed no aluminum content.

Gear Failure

Gear wear was found to have been so severe that the transmission was regarded as having failed. Photographs in Appendix I show the extent of damage, probably very largely the result of clash-shifting made especially severe at a standing start because of high clutch drag in the multi-disc dry clutch. The metal battered from the gear teeth was found in the bottom of the case. Analysis of the half cup of solid material removed showed an all steel content - no sand or aluminum casting fins, as was first suspected.

In addition to battering at the ends of the teeth, there was extreme wear across tooth faces. This may have been a secondary result of battering of the edges, but might have occurred anyway, - especially in view of a similar though less severe wear of the final drive gears. It was judged to be a lubrication failure, one that could certainly have been postponed through the use of extreme pressure type of lubricant. No E.P. additives were found when the transmission oil was analyzed.

No special provision had been made for cooling the transmission oil. There was no cooler or separate reservoir, nor was the aluminum case finned.

The face wear on the gear teeth was found to be tapered across the gear, giving the teeth a twisted appearance. This wear pattern may have been the result of the bending and twisting of the shafts carrying the gears. Twisting of the shafts under torsional load could be expected to cock the splines and therefore the gears, and excessive and tapered gear wear could then result for two reasons:

1. Uneven load distribution across the gear.
2. Slow, creeping disengagement, which in turn would cause further load shift.

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Transmission case distortion under load might also have contributed materially to the excessive gear wear.

The most extreme wear had occurred on the 1st and 2nd speed and reverse gears, where the clash shifting damage could be expected to be most severe. Complete failure appeared imminent. If the 1st speed gears became unusable, reverse would be lost as well. All the other ratios were independent, however, and the stripping of one set would not affect the others (except that steel fragments could jam in and hasten the destruction of the other gears). In any case, the transmission appeared to be a weak link in the T34 tank.

Transmission Service

The following steps must be taken to remove the transmission from the vehicle:

1. Disconnect 3 transmission rods, 2 brake control rods, 2 clutch control rods (for the steering clutches). All connections are made by means of clevis pins held by cotters.
2. Disconnect electric wiring at the starter motor relay.
3. Provide auxiliary support for the transmission, then remove capscrews to allow the steering brake drums to be pushed toward the center of the transmission (and thereby away from the final drive flanges) to permit the transmission and steering brake and clutch assembly to be lifted out. Unbolting the supporting stout at the input end completes this preparation.

For disassembly of the transmission, the steering clutch and brake assemblies must first be removed from the overhanging ends of the output cross-shaft to permit access to the studs that hold the cross-shaft seal retainers. These retainers and the one at the input pinion straddle the two halves of the transmission case and thereby prevent access until they are removed.

Transmission Case Machining

It appears that the bottom face of the lower transmission case and the top face of the upper were machined by a vertical lathe, such as a Bullard. These faces were machined all over because very little machining time could be saved if all the necessary bosses were to be machined separately.

Greater machining speed might have been obtained, had a series of fly cutters been used to traverse the entire surface in one pass. This would have required a special machine.

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After these two outer surfaces - top and bottom - were machined, the two halves of the transmission case were turned over and the mating surfaces machined, again using a vertical lathe. The nine holes for the through bolts were then drilled in each half, starting at the mating surface in each case in order to insure proper alignment at these surfaces. Possibly the holes for the bolts around the mating flanges were also drilled from the mating surface, although these were short holes. Either a radial drill or a drill press would have been adequate for this purpose, since undoubtedly a drill jig was used. Then before the two halves were bolted together for further machining, the end of the center web opposite the entrance for the pinion assembly was faced off. This appeared to have been done on a horizontal lathe or a boring mill with a fly cutter. The two halves were then turned over and all the holes previously drilled were spot faced. Then the two halves were bolted together and a horizontal boring mill was used to bore the bearing pedestals in the three webs.

It is very likely that the three bearings in line for each of the two cross-shafts were bored simultaneously with a boring bar. A horizontal boring mill would also have served to bore the boss for the pinion assembly and to face this boss.

The two sides of the transmission case assembly were also faced off with the two halves bolted together. This facing could have been done either before or after the boring operations and was probably done before. Apparently a horizontal mill was used. Flanged surfaces around the bored holes were finished by spot facing after this milling operation.

The inside faces of the end bearing recesses were machined only for clearance for the ears. This machining was done apparently by horizontal milling. The faces of the bearing recesses in the center web required for precise flatness and squareness and were therefore faced either with a boring bar or a fly cutter.

In summary, it appears entirely possible that all machining on the two castings forming the transmission case might have been done by four machines: a vertical lathe, a horizontal lathe, a horizontal boring machine, and a drill press or radial drill. There is no way of knowing whether production rate had been increased by doing several operations simultaneously. It would have been possible to face the two sides of the combined castings by simultaneous milling. Gang drilling could also have shortened production time.

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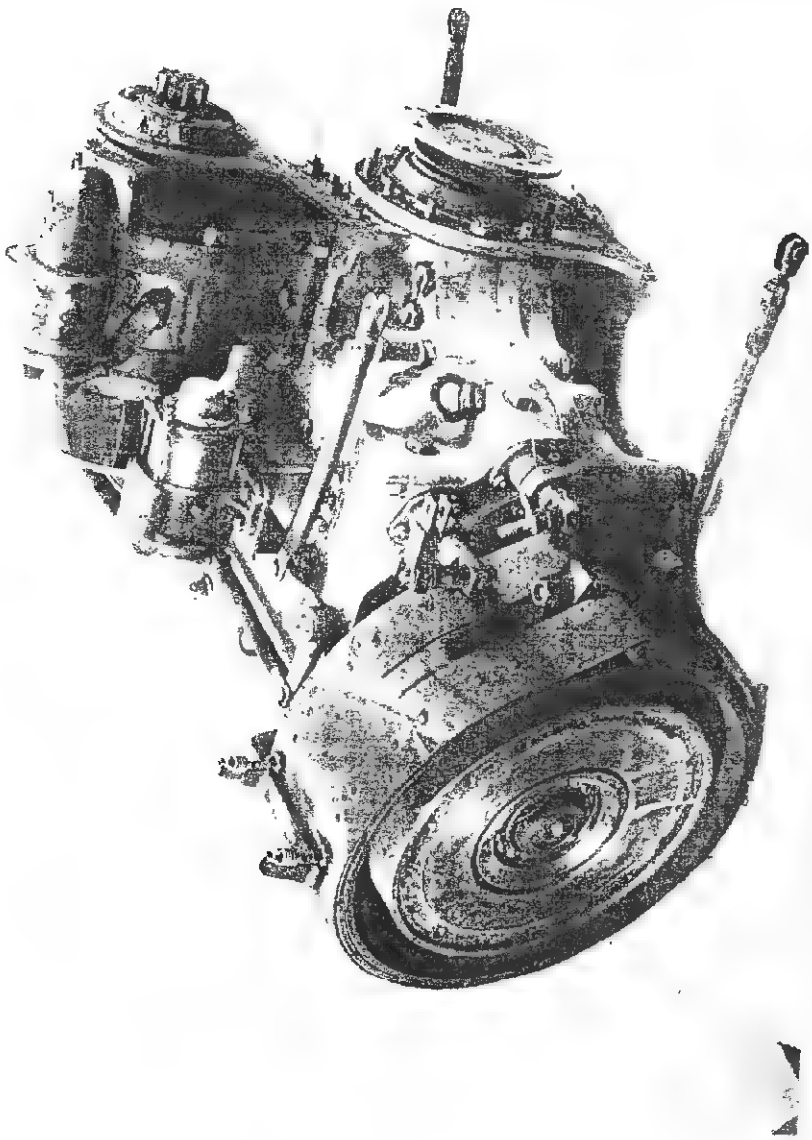

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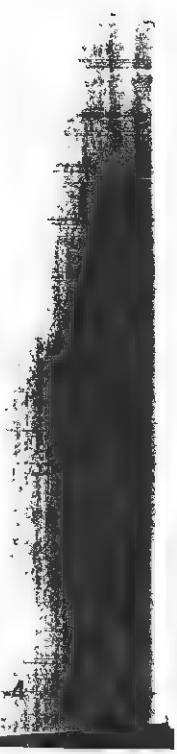
0700 f TRANSMISSION ASSEMBLY

1. Input cross-shaft
2. Roller bearings
3. Output cross-shaft
4. Second speed driven gear
5. First and second gear cluster shifting rail
6. Reverse idler gear cluster shifting rail
7. Reverse idler gear cluster
8. Third and fourth gear cluster shifting rail
9. Fourth speed driven gear
10. Third speed driven gear
11. Third speed drive gear
12. Fourth speed drive gear
13. Input bevel gear
14. Input pinion assembly
15. Cross-shaft thrust bearings (double tapered roller)
16. First speed driven gear
17. First speed drive gear
18. Second speed drive gear



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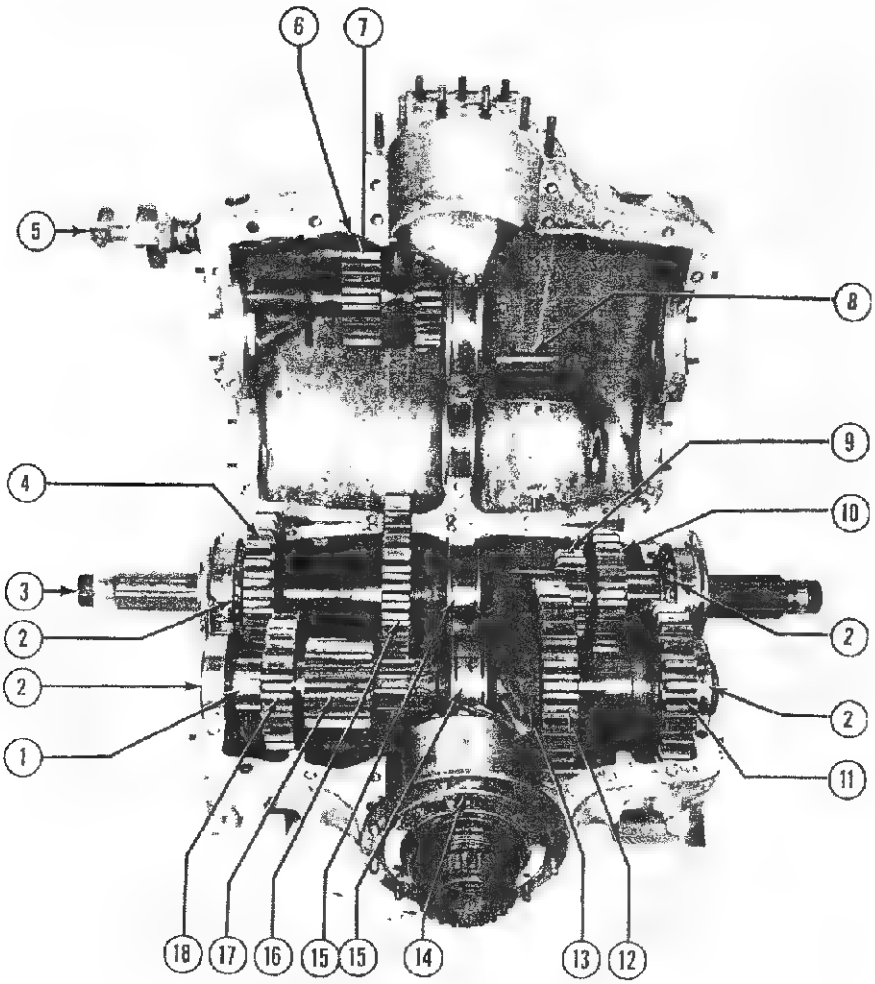

0700 f TRANSMISSION ASSEMBLY

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0702.1 - TRANSMISSION DRIVE PINION ASSEMBLY

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0702.3 - TRANSMISSION OUTPUT CROSS-SHAFT ASSEMBLY

1. Second speed driven gear
2. Roller bearing
3. Thrust bearing preload nut and washer
4. Thrust bearing assembly
5. Third and fourth gear cluster shifting assembly
6. Output cross-shaft
7. Roller bearing
8. Third and fourth speed gear cluster
9. Oil throwers
10. Roller bearing outer race and bearing support assembly
11. Gear spacers
12. First speed and reverse gears, driven

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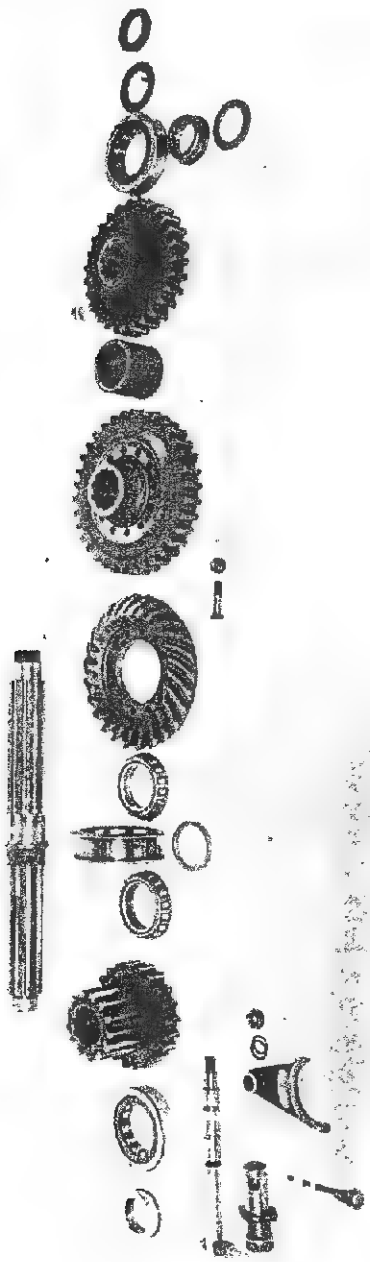

0702.5 - TRANSMISSION INPUT CROSS-SHAFT ASSEMBLY

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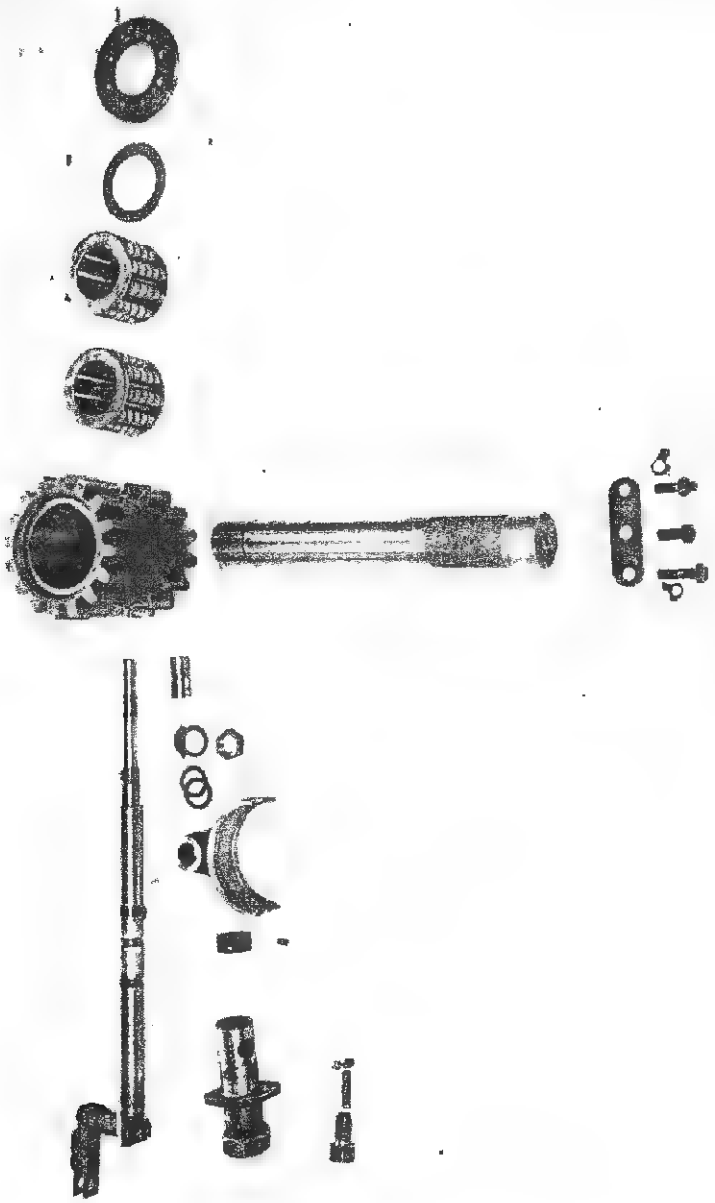

0702.5.5 - REVERSE IDLER ASSEMBLY

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STEERING CLUTCHES

The two steering clutches were similar in design and operation to the main clutch. Each steering clutch consisted of 37 alternate drive and driven discs (19 driven discs, 18 drive discs plus two pressure plates), which were compressed by 18 springs. Some of the steering clutch parts were interchangeable with main clutch parts.

The Aberdeen report mentioned difficulties with the steering clutches slipping. There were no indications of excess slippage of the G812 clutches. The Aberdeen report also mentioned a total of 43 discs in each steering clutch compared to the 37 in the G812 tank.

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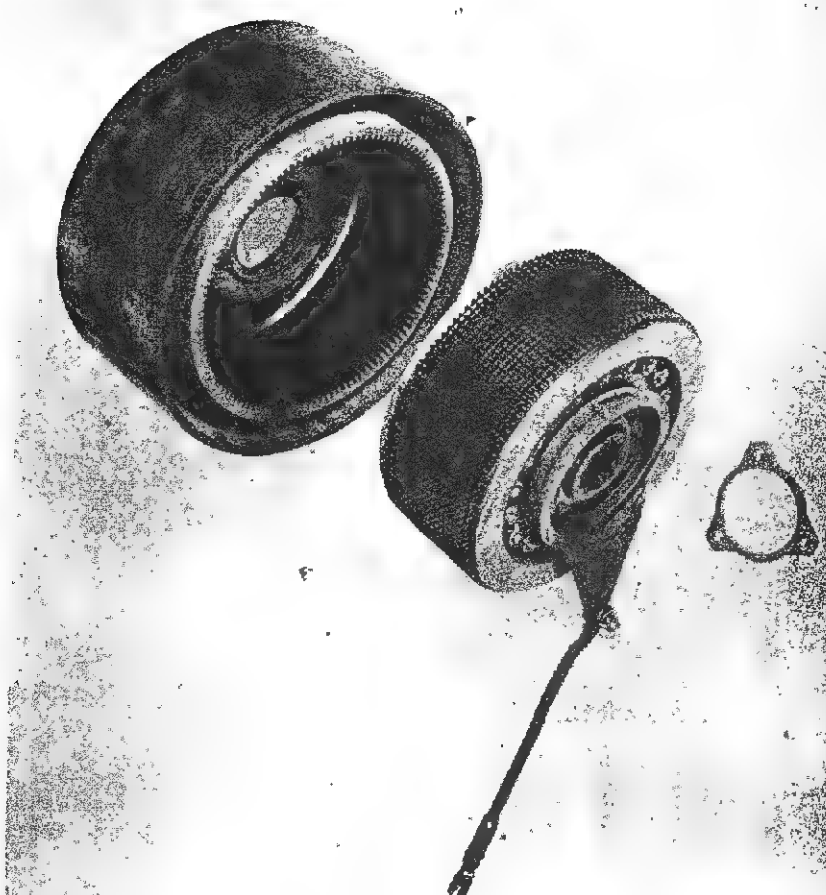

0726.1 - STEERING CLUTCH

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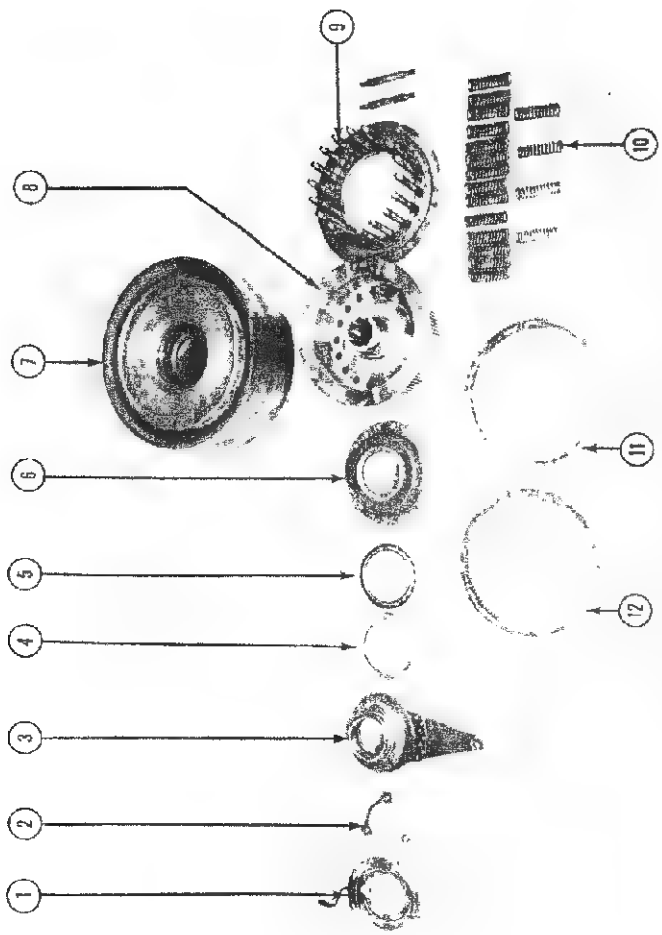

0726.1.2 - STEERING CLUTCH ASSEMBLY

1. Fixed clutch pressure ramp
2. Clutch pressure ball assembly
3. Clutch pressure arm and movable ramp
4. Thrust ring
5. Ball thrust bearing
6. Bearing retainer and pressure release plate
7. Driven drum
8. Drive drum
9. Pressure plate
10. Pressure springs
11. Driven clutch plate
12. Drive clutch plate

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STEERING BRAKES

Steering brakes were the external-contracting type and acted on a drum which was joined to the driven steering clutch drum by a web, the two drums being cast as a unit. The provision of two concentric drums resulted in much greater heat dissipating surface and especially in lessening the amount of brake heat reaching the clutch. The gap between the two drum surfaces is about 1-1/2 inches. The depth from either end to the center rib is 3-1/2 inches, the rib being 1 inch thick and the drum width 7-15/16 inches. The brake drum circumference is 62 inches.

The brake linings were of cast iron. The Aberdeen report mentioned "Ferrado" brake linings.

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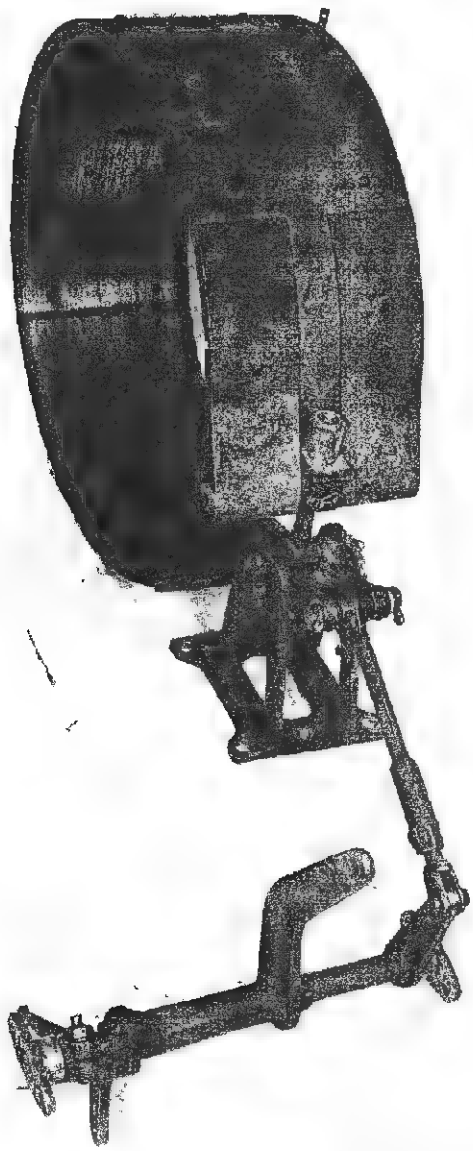

0727 - STEERING BRAKE ASSEMBLY

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FINAL DRIVE

The gear ratio of the final drive was 57/10 = 5.70. (Aberdeen reported 5.714) All gear teeth were stub design rather than the more expensively made involute tooth.

The final drive output shaft was supported by two tapered roller bearings, one of which was American made. The input shaft was supported by a self-aligning, double barrel roller bearing and a straight roller bearing. The input shaft also supported the transmission assembly, through the flanged connection.

The speedometer cable was connected to a brass worm gear arrangement on the left output shaft.

Dust and oil seals were felt.

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1008.1 - FINAL DRIVE ASSEMBLY

1. Self-aligning, double row, tapered roller bearings
2. Speedometer drive
3. Grease seal and speedometer drive housing
4. Bull gear
5. Bull gear shaft
6. Tapered roller bearing
7. Final drive housing
8. Tapered roller bearing, American made
9. Track drive wheel
10. Roller bearing assembly
11. Final drive pinion
12. Input flange (bolted to steering brake-clutch drum

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SUSPENSION

The parts shown in the accompanying picture are used in eight of the ten suspension assemblies; all but the front two. The trunnion or short pivot shaft for each suspension arm operates in a steel tube welded into the tank hull and provided with a steel bushing. The shaft is prevented from pulling out of this tube by the three-holed steel plate shown immediately to the left of the trunnion and arm assembly (photograph 1301.1). This plate is inserted in the notch in the suspension arm and is bolted to the tank hull.

Two coil springs are used in series. Alignment is maintained by the flanged bushing which pilots in adjoining ends of the two springs and allows the passage through it of the telescoping guide member. This guide member offers no shock absorber action. The three-holed plates and their pins shown at each side of the upper half of the telescoping guide member provide a means of assembling the springs and these upper parts from above.

No seal is provided against water, mud, or dirt at any point in the suspension. The tubes that carry the suspension arm trunnions are provided with grease fittings. Apparently, the addition of grease from time to time is expected to push dirt out. Pieces of heavy canvas had been laid in the top of the rectangular cross-section tube that provided the housing for each pair of springs. Apparently, the rectangular tube was packed with heavy grease and the canvas was then laid on top. Extra grease was packed on top of the canvas and the rectangular tube was then covered with a piece of armor plate bolted in place. The canvas was a poor fit in the rectangular tube and furthermore had a round hole in the center about two inches in diameter. Possibly, it was the intention to have the canvas allow a slow feed of grease into the suspension, especially as need was indicated by rising temperatures such as would melt the grease and allow it to pour through, out and around the canvas. There was no retainer at the bottom of the assembly, however, and any grease becoming fluid enough to pass the canvas would probably run right through the suspension parts, or perhaps only down the side of the rectangular suspension housing and out the bottom.

The two front suspension systems differed from the others in that the two coil springs were not in series but were concentrically arranged and were inside of the hull, rather than in housings which were welded to the hull. The coil springs were guided by a rod which was pinned to an arm splined to the suspension arm shaft. Clearances between the rod eye and the splined arm were not adequate, and bending of the guide rods accompanied by excessive wear had occurred.

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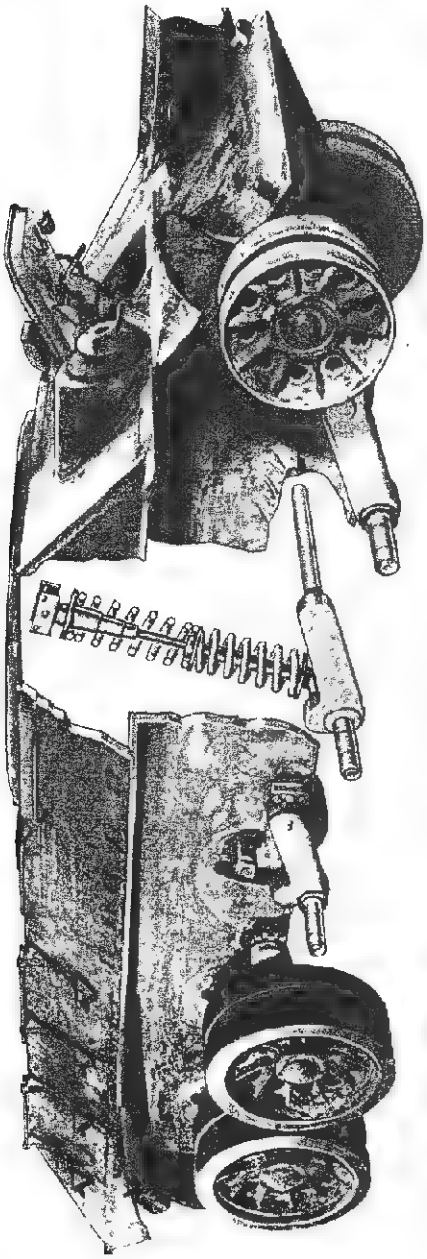

1800 f - HULL, CUT-AWAY VIEW SHOWING SUSPENSION

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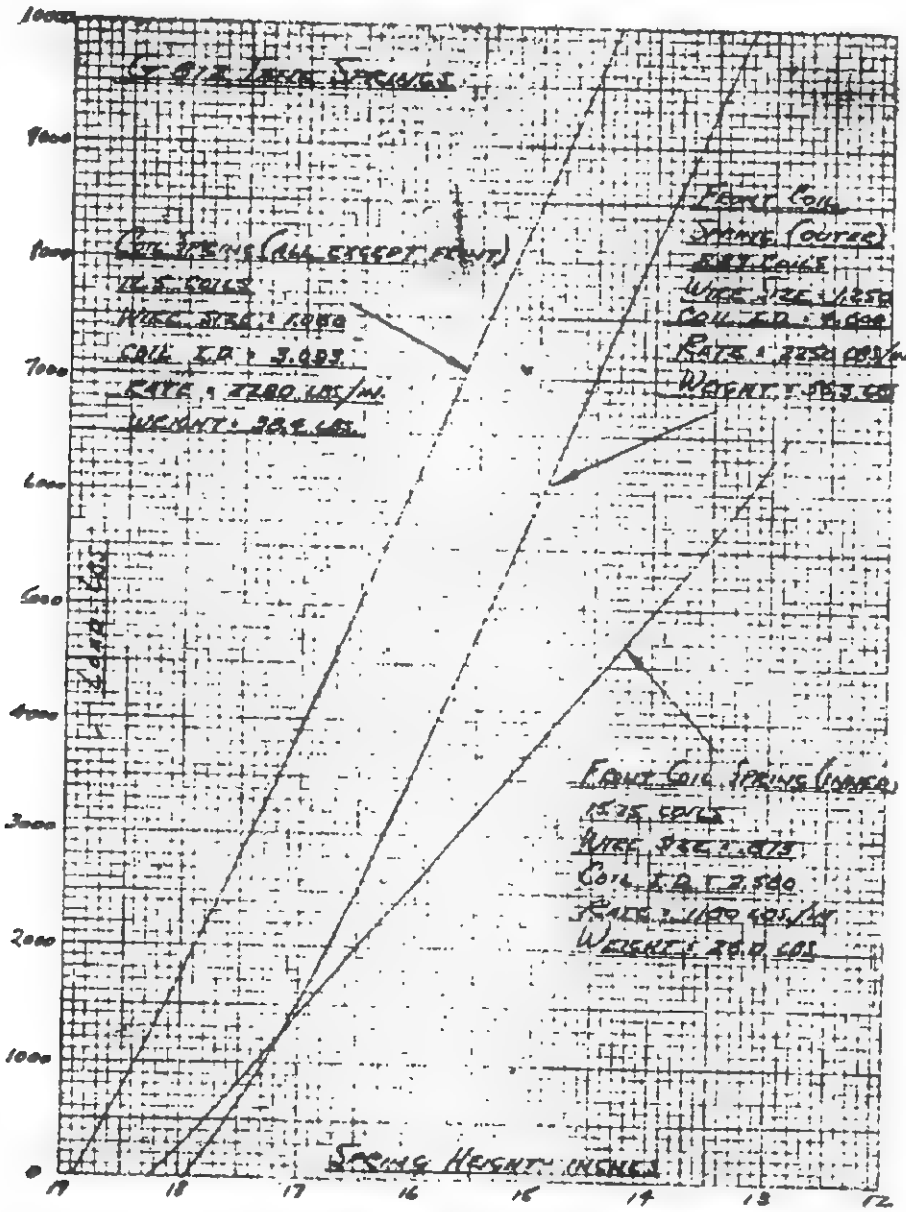
G612 TANK SPRINGS



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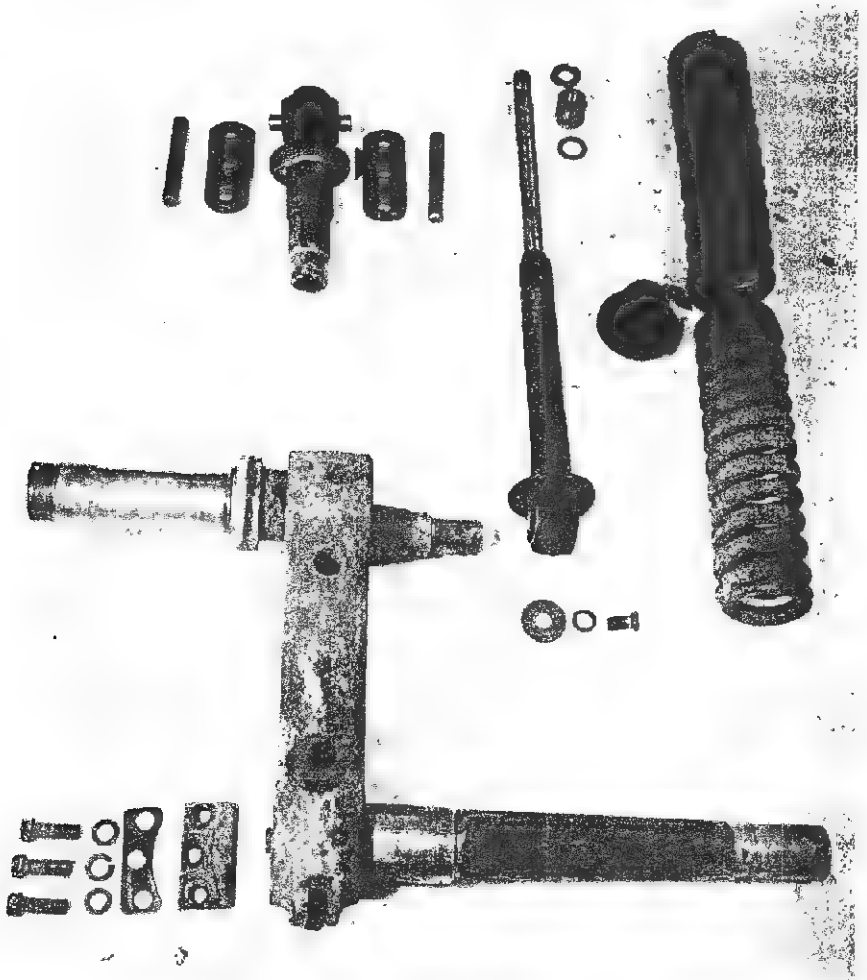

1301.1 - REAR SUSPENSIONS ASSEMBLY

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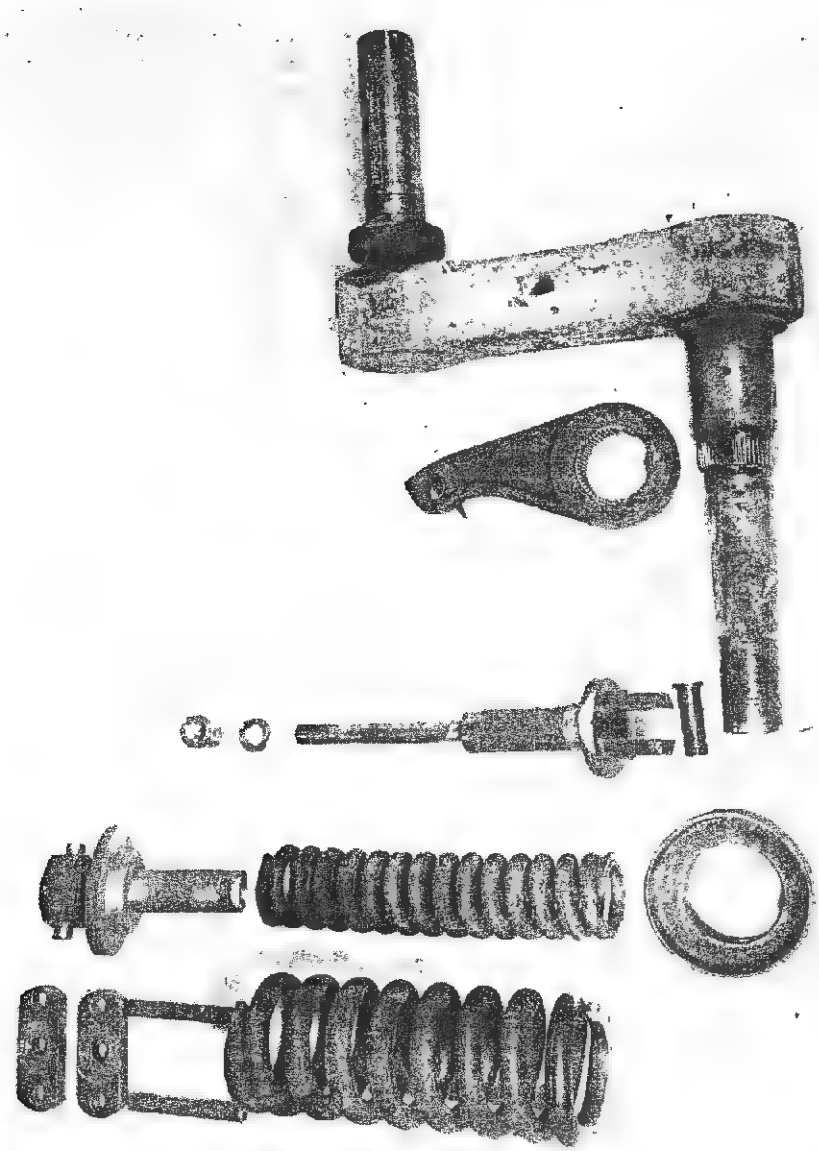

1301.0 - FRONT SUSPENSION ASSEMBLY

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TRACK TENSION ADJUSTING MECHANISM

A track idler wheel, mounted on an adjustable eccentric arm, was provided for maintaining proper tension in the track. The eccentric arm was locked in the proper position by matching serrations on the arm and hull. The arm serrations are kept in close contact with those on the hull by pulling the arm with a large nut, splined for a nut locking mechanism and special ratchet wrench.

The idler wheel was on two anti-friction bearings; one an American made ball bearing and the other a Russian made roller bearing.

The locking system used for the splined nut was a spring loaded pin, located on the collar forming part of the worm gear housing, that engaged one of the spline grooves and prevented rotation of the nut. The Aberdeen report said that the nut was pinned to the eccentric shaft by a removable through pin.

The tension in the track was taken up by a worm gear arrangement. The gear was splined to the eccentric arm and the worm shaft was reached by removing a plug from the front exterior of the hull. The worm shaft could then be turned with a special wrench until proper track tension was obtained.

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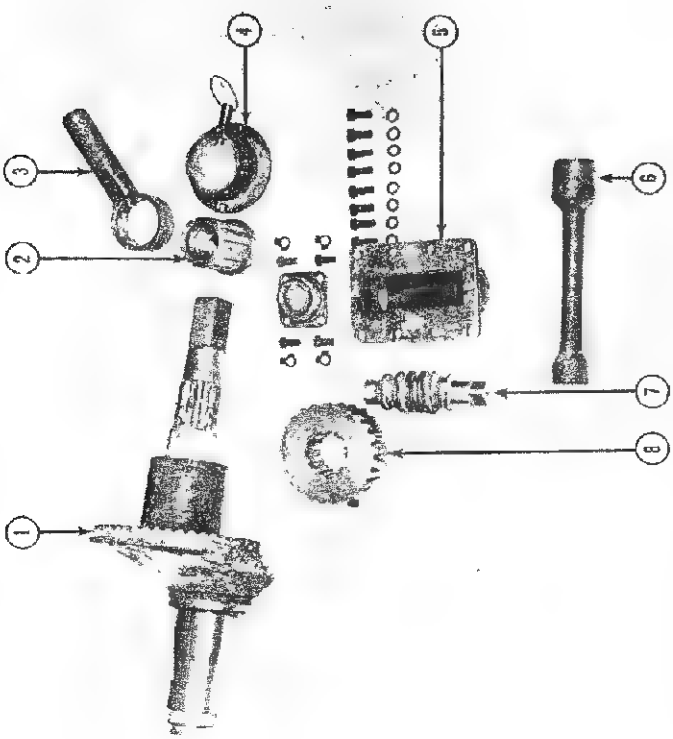

1303.1 - TRACK TENSION ADJUSTING MECHANISM

1. Track idler wheel arm
2. Track idler wheel arm locking nut
3. Special wrench for locking nut
4. Locking mechanism to engage splines on locking nut
5. Worm shaft housing
6. Special wrench for worm shaft
7. Worm shaft
8. Worm gear

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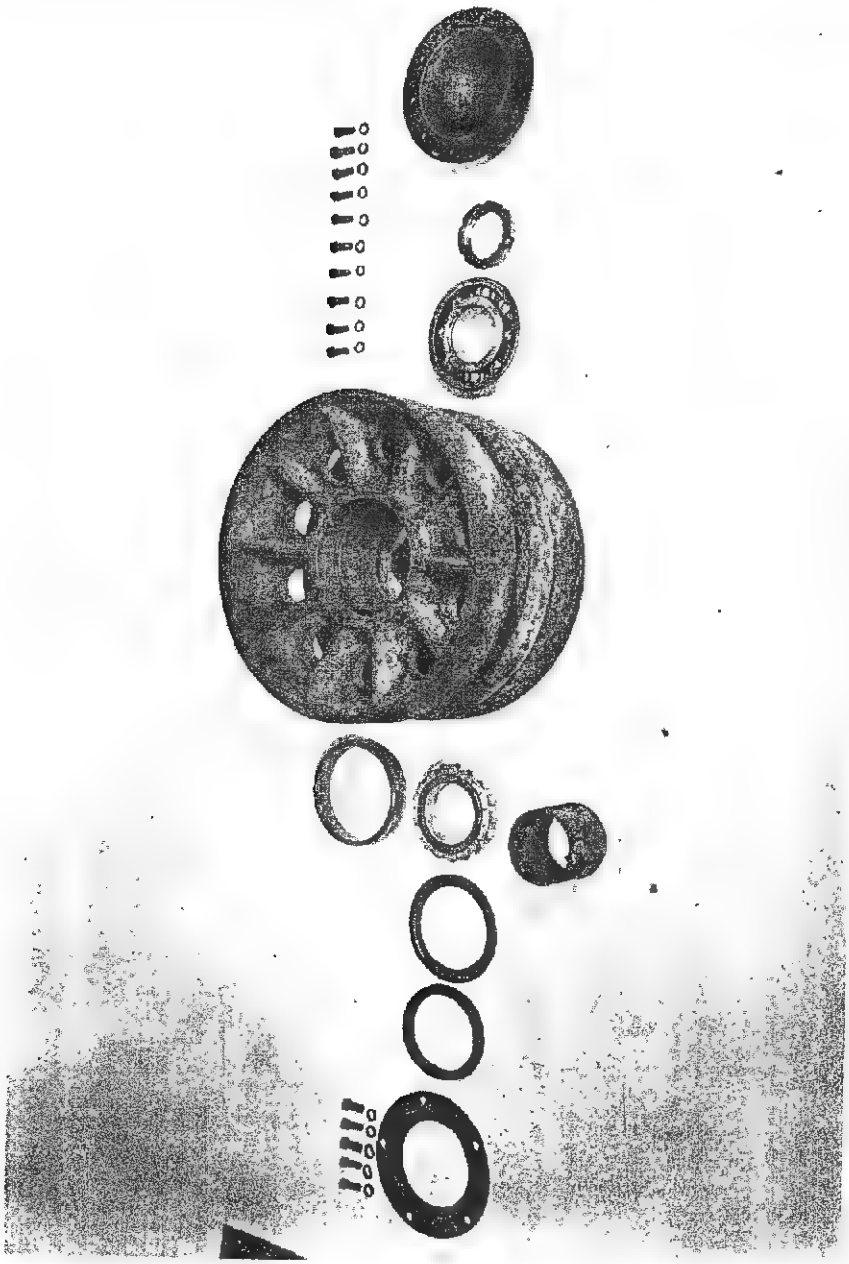

1303 - TRACK IDLER WHEEL

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MECHANICAL CONTROLS

These include the following:

1 - Accelerator pedal and hand throttle control,

2 - Brake pedal, with ratchet to provide a brake lock for parking,

3 - Two steering control levers - one left and one right,

4 - Clutch pedal for the main clutch,

5 - Transmission shift lever.

1 - The hand throttle control was obtained by a lever and over-travel linkage that worked directly on the foot control.

Pushing the accelerator pedal put the control rod in compression. Motion is transmitted through several bell cranks to the injection pump governor on the engine. The throttle return spring was mounted on the front end of the engine. This allowed backlash between this spring and the injection pump governor lever to provide uncertain control. An additional throttle return spring was provided on the rod running along the floor of the hull.

2 - The brake pedal operated on both the final drive brakes through an over-travel lever mounted at the center of the two control countershafts and piloting on both of them. This over-travel lever permitted taking control of the brakes without operating the corresponding final drive clutches.

3 - Each steering control lever operated a corresponding final drive clutch and picked up control of the corresponding brake. Overcenter springs were provided for these controls, apparently as an answer to the earlier complaints of high force required. An additional provision for ease of steering was the hook-shaped cam at the lower end of the steering lever. This cam operated on a roller of a mating bell crank to provide a high and changing mechanical advantage.

4 - Clutch pedal operated the main clutch between the engine and the transmission and was also provided with an overcenter spring to minimize the amount of force required to operate it.

5 - The transmission shift lever was of the welded-stick type. It was made to operate one of three shift control rods, each moving a corresponding cluster gear in the transmission. Ball interlocks were provided in the mechanism at the base of the shift lever to prevent either of the other two rods from moving after one had been selected. An additional squeeze lever was provided on this shift lever to prevent accidental shift into reverse. When this lever was squeezed against the shift knob, only the four forward speeds could be obtained.

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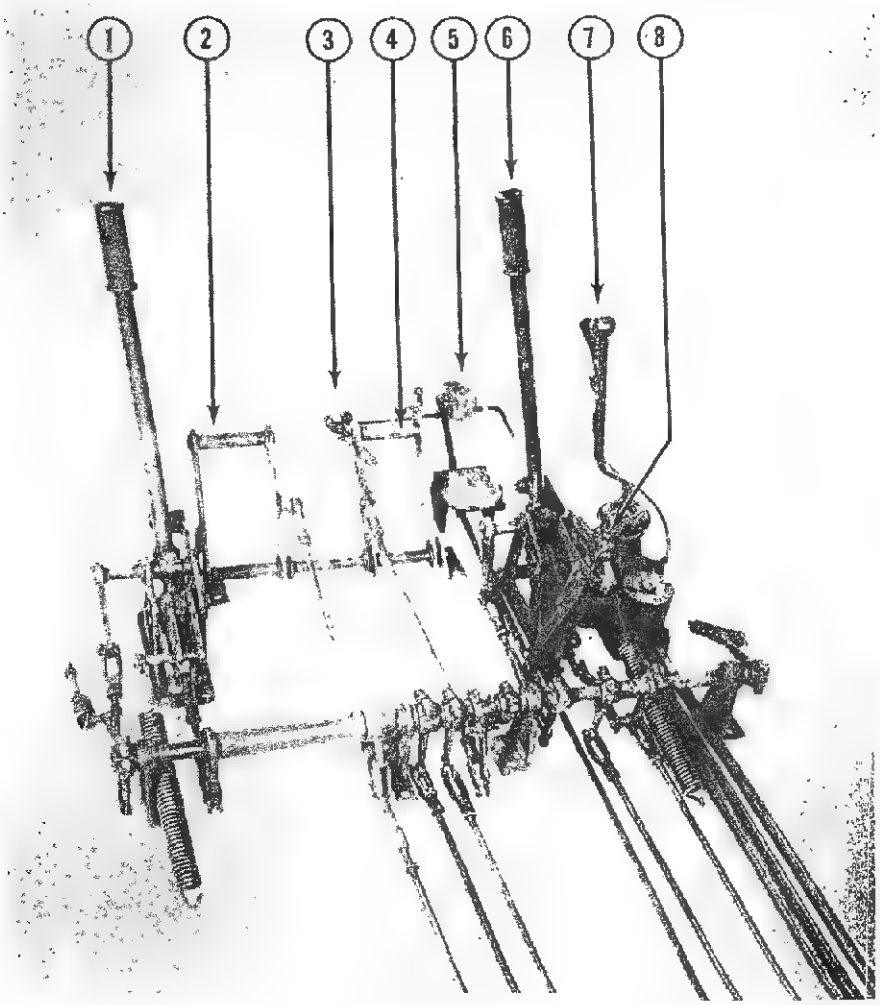

1400 - DRIVER'S OPERATING CONTROLS

1. Left brake and steering clutch lever
2. Main clutch pedal
3. Brake pedal locking device
4. Brake pedal (both brakes)
5. Accelerator pedal
6. Right brake and steering clutch lever
7. Transmission gear shift lever
8. Accelerator lever for hand control

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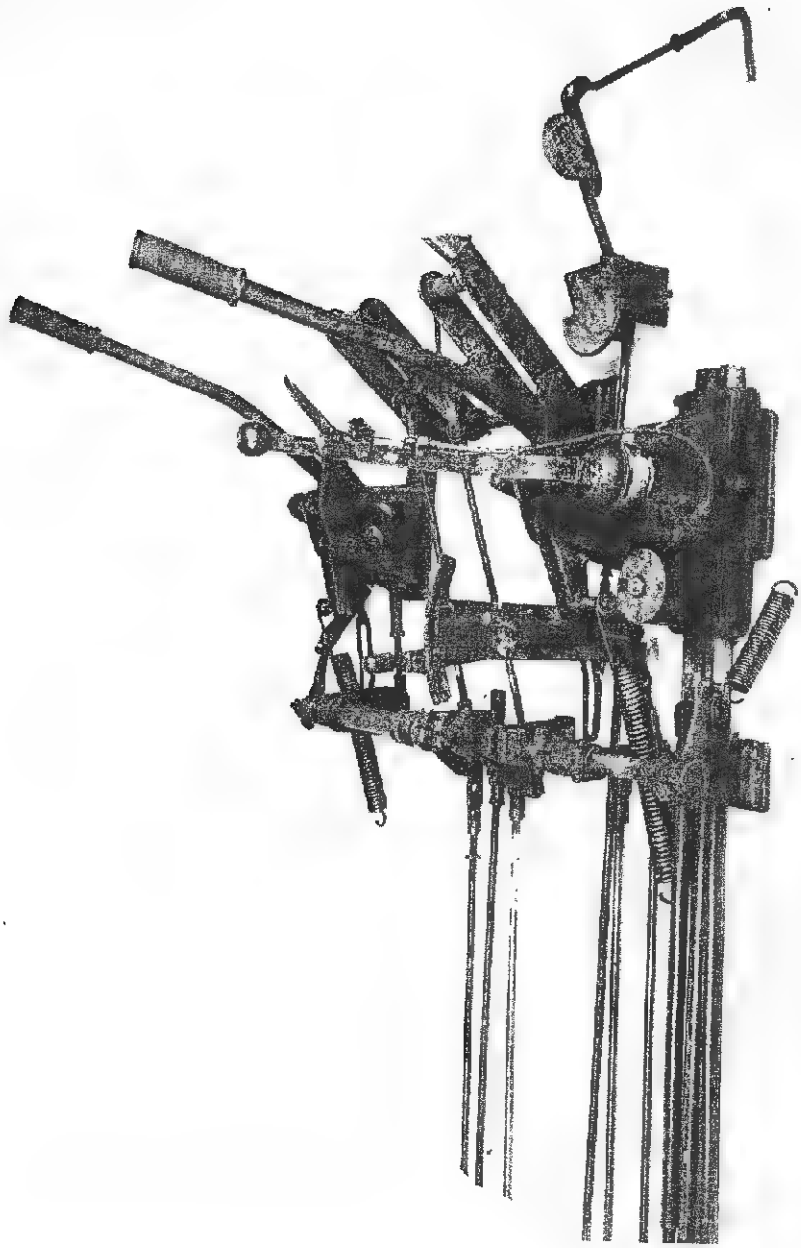

1400 a - DRIVER'S OPERATING CONTROLS

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HULL

The hull construction was essentially the same as that of the Aberdeen tank. Differences noted are the new V-edge front, instead of the rounded casting on the Aberdeen tank, the presence of rails and hooks on the G812 tank, the use of three hinges to support the rear armor plate rather than the two on the Aberdeen, and slight changes in armor plate thickness on the G812 tank. Armor plate thicknesses are shown in the table below:

Location	Thickness	
	Aberdeen Tank	G812 Tank
Front	50 mm	45 mm
Sides	20	45
Hull Top	20	20
Engine Cover	20	20
Rear Plate	45	45

A repair weld had been made on the front armor plate. Armor welding appeared to be sound and was fairly smooth. More details are given in the Metallurgical report in the Appendix.

No bilge pump was provided in the hull to drain accumulated oil or water from the floor of the tank. Control rods, ammunition boxes, and other obstructions would make bailing difficult. The hull could be drained by removing a number of plugs which were provided for draining oil and fuel tanks. The plugs can be removed only from the outside of the tank.

There is a removable rectangular plate on the hull bottom, directly below the front of the engine. This is undoubtedly for servicing the oil and water pumps. Another plate (circular) is located below the transmission oil drain plug. There are other openings below the oil and fuel tank plugs for draining of those tanks. The water system is drained through a tube welded through the hull bottom. These openings and others for filling oil and fuel tanks make all regular servicing of the tank easy to do in the field, except for servicing of the new type air cleaner. This requires removal of several heavy pieces of armor.

A circular plate, directly below the main clutch assembly, had been cut from the hull bottom and then welded back in place. Reason unknown.

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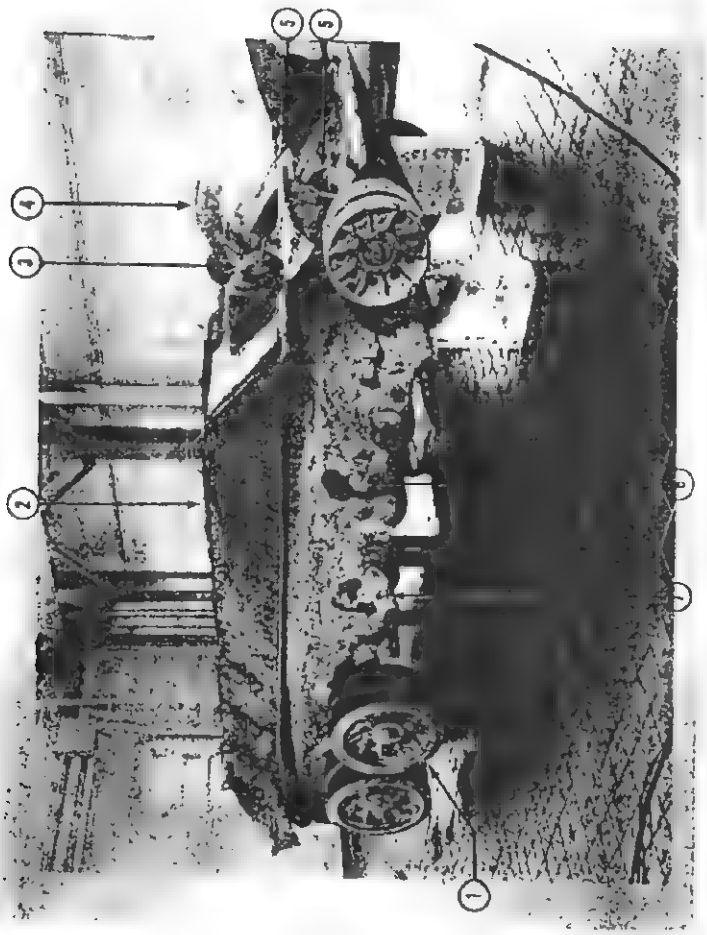

1800 b - HULL, PARTIALLY STRIPPED

1. Bogie wheel
2. Turret ring
3. Machine gun mount
4. Driver's hatch
5. Lifting hooks
6. Suspension arm bumper
7. Suspension arm

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- HULL PARTIALLY STRIPPED

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1200 d HULL, STRIPPED OF ALL REMOVABLE PARTS

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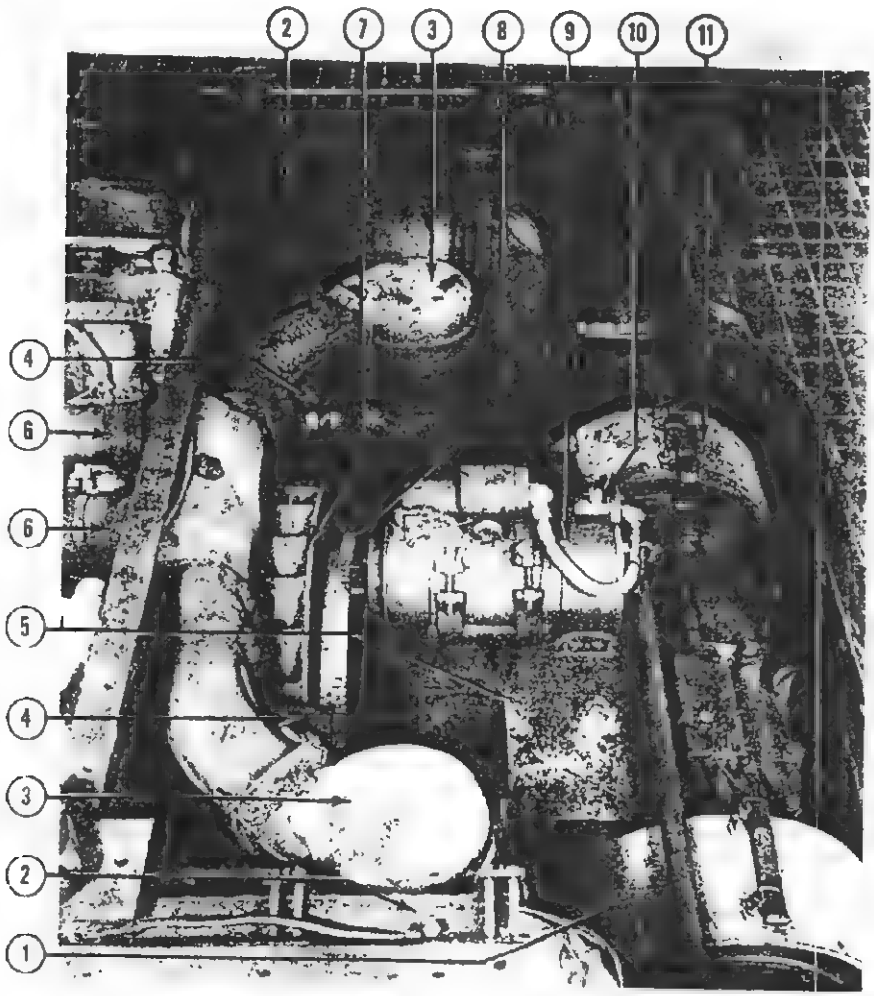

1800.8 - HULL, REAR WITH ARMOR REMOVED

1. Left brake
2. Rear fuel tanks
3. Air cleaners
4. Exhaust pipe
5. Transmission housing
6. Air intake manifolds
7. Fan
8. Starter ring gear
9. Starter
10. Starter relay
11. Right brake

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ARC.11 - HULL, ENGINE COMPARTMENT

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ACCESSIBILITY OF ENGINE PARTS FROM FIGHTING COMPARTMENT

The bulkhead between the engine and the fighting compartment was provided with removable panels for easy access to many of the engine parts and for ventilating the fighting compartment using the engine cooling fan.

Controls operated from this area are the air vent louvers, the scavenger oil control valve, the hand operated oil pump, the water system drain valve, and the fuel tank selector valve.

The batteries are serviced by sliding them into the fighting compartment through openings at each side of the engine. The water pump lubrication assembly may be serviced through the bottom center opening. Other engine parts that can be reached through this opening are the oil manifold, the fuel transfer pump and the water pump. The upper center opening permits access to the scavenger oil control valve, the air starter distributor, the fuel filter, the crankcase breather tube, the oil filter, and the tachometer drive.

All of the panels are fastened by bolts with wing nuts for easy removal.

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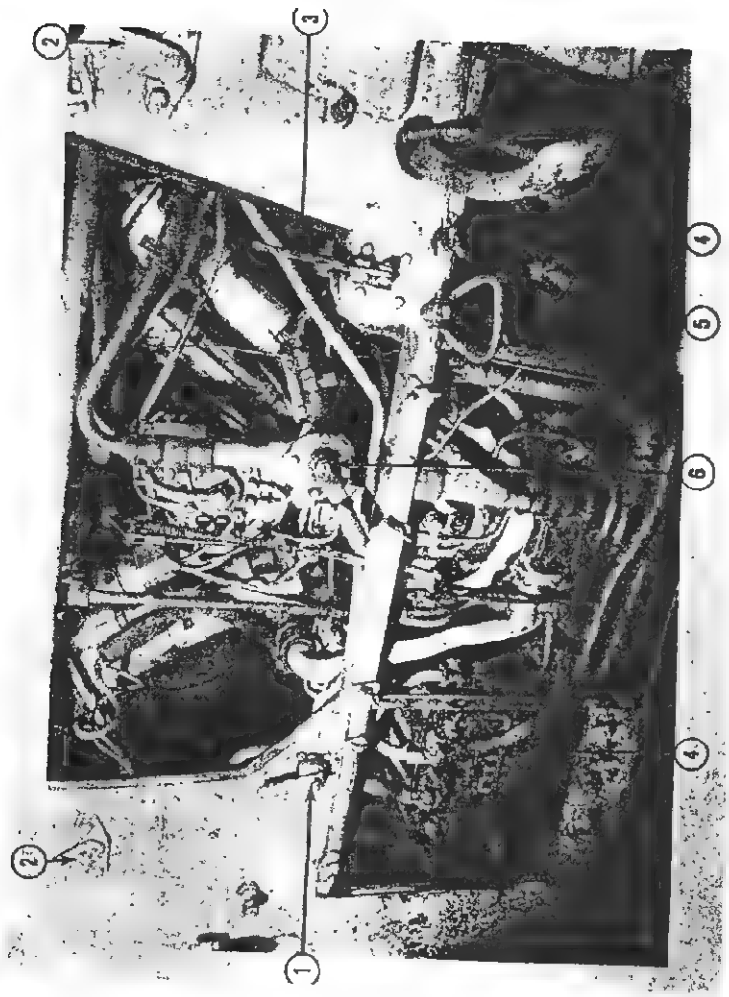

1800.14 - ENGINE AS SEEN FROM FIGHTING COMPARTMENT

1. Fuel tank selector valve
2. Air louvre control arms
3. Hand-operated oil pump
4. Battery
5. Water system drain valve control
6. Scavenge oil control valve

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1800.15 - DRIVER'S COMPARTMENT

1. Driver's hatch counter-spring assembly
2. Track tightening mechanism lock nut
3. Machine gun mount
4. Escape hatch
5. Main battery ground switch
6. Driver's seat

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1800.16 - DRIVER'S COMPARTMENT, LEFT SIDE

1. Fire extinguisher
2. Main electrical control panel
3. Valve, air starting system
4. Switch, electric starting system
5. Front suspension assembly
6. Fuel tank pressurization selector valve

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1800.19 - HULL INTERIOR, FIGHTING COMPARTMENT

1. Slip ring assembly for turret electrical supply
2. Left brake control rod
3. Left clutch control rod
4. Main clutch control rod
5. Transmission control rod, first and second gear
6. Transmission control rod, reverse gear
7. Transmission control rod, third and fourth gear
8. Right brake control rod
9. Right clutch control rod
10. Accelerator control rod

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TURRET

The turret on the G812 tank was made by casting the sidewalls and welding a rolled steel plate on the top. Another steel casting was bolted to the gun carriage assembly to cover the openings in the turret front for the tank gun and component mechanism.

Two hatches were provided on the turret top. One opened flush with the top plate, while the other was on a cast steel cupola welded to the top plate. The hatch on the cupola was equipped with a ball race to permit rotation of the hatch for use of the periscope mounted on it. Both hatches had countersprings to make opening easier. The cupola had observation slits cut in it. Over each slit, on the inside of the turret, was a sliding device that covered the slit with either a two-ply glass window or a steel plate. There was one pistol port on each side of the turret.

The turret was provided with several periscopes. Four lifting hooks were welded to the turret for lifting it from the hull. A large ball bearing arrangement was used to support the turret on the hull and permit its rotation. Electrical supply to the turret was through a slip ring assembly located in the center of the turret.

An antenna base mounted on the turret top and loose wires found inside the turret indicated that a radio had been installed in the turret. There was no radio in the tank when it was received. The Aberdeen tank had a radio, but it was located in the hull at the right of the machine gunner.

The G812 tank was equipped with an 85 mm tank gun instead of the 76 mm gun discussed in the Aberdeen report. The sighting mechanism and the coaxial machine gun mentioned in the Aberdeen report were not in the G812 tank when received, nor was there enough of any such mechanism to determine whether the same system was still being used.

The gun elevating mechanism was a simple hand-operated worm gear arrangement which acted on a spur gear. The spur gear meshed with a gear sector, which was bolted to the gun recoil mechanism.

The turret could be traversed by hand or by an electric motor with two-speed hand control in either direction. In either case, the motion was obtained by a 13 tooth drive pinion operating on a 362 tooth turret ring gear, the resulting mechanical advantage being 27.8. Both mechanical and electrical drive was through an irreversible worm gear providing a mechanical advantage of 36. The hand crank operated this worm directly, while the motor drove it through a pair of spur gears, providing a further mechanical advantage of 63/13 or 4.84. Thus the total reduction for the motor drive was 4,840 and for the hand crank was 1000. These gears were always in mesh and the motor was therefore always turned whenever

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the turret was operated by hand. The hand lever was clutched to the larger of these spur gears for hand operation, but was declutched and made to operate a barrel switch for control of the electric motor when electric operation was desired.

The electric motor provided for turret drive was a series motor running on precision ball bearings. Control was provided by a barrel-type reversing switch with intermediate armature contacts that insured starting of the motor through a resistance in the armature circuit. The resistance was cut out when the control handle was moved to the full speed position. The motor and switch were very sturdily made. There was no indication of contact or commutator burning.

The output of this turret drive was operated through a dual cone clutch which could not be released but was apparently provided to prevent damage to the traversing machanism, if the turret were forced into sudden rotation as by the gun catching on a tree when the tank is in motion.

The turret traversing mechanism was provided with five ball bearings. Two of them were in the electric motor, two on the worm shaft, and one on the output shaft. The following are the ball bearings used:

	ID	OD	Width
Motor, pinion end	16 mm	40 mm	11 mm
Motor, commutator end	12	32	10
Worm shaft, spur end	20	62	17
Worm shaft, pilot end	20	52	15
Output shaft, worm gear end	20	52	15

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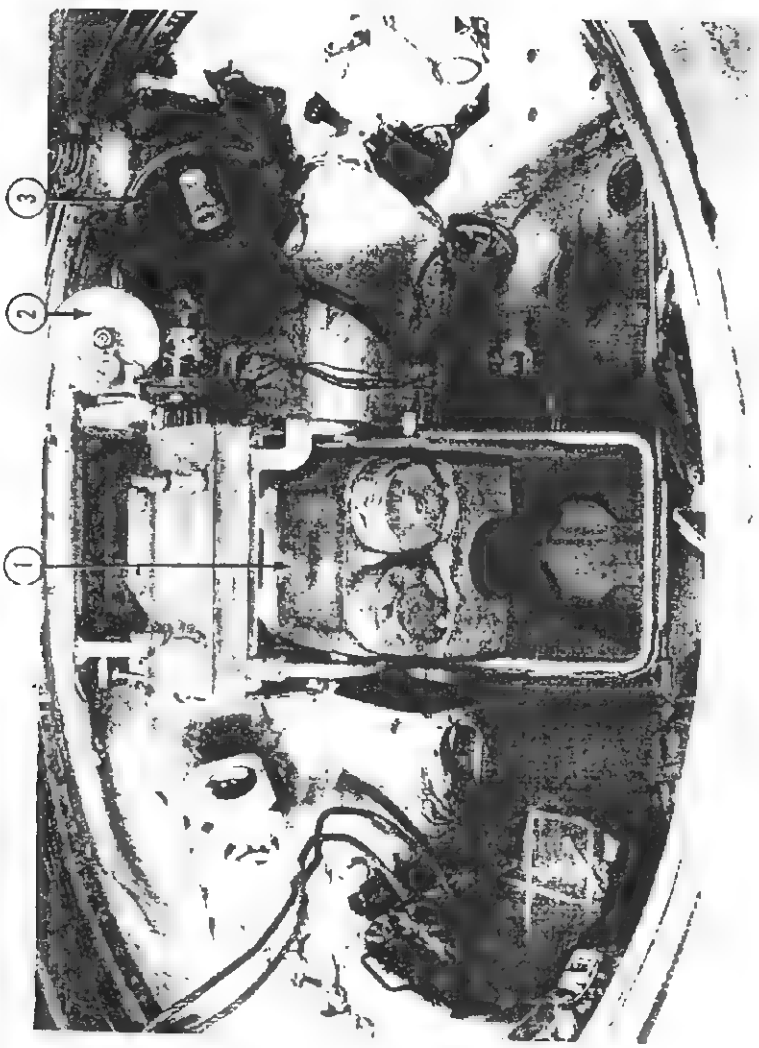

1900 - TURRET INTERIOR (INVERTED)

1. 85 m.m. tank gun
2. Gun elevating mechanism
3. Turret traversing mechanism

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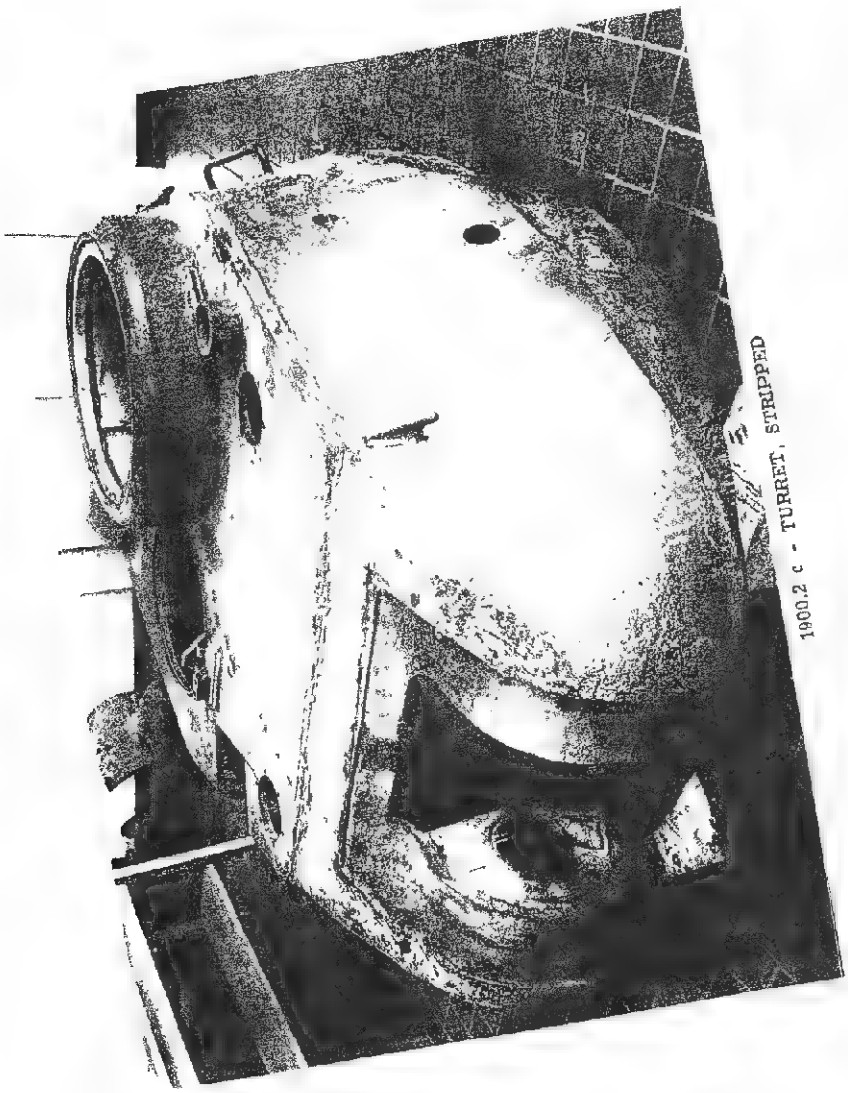
TURRET



1900.2 c - TURRET, STRIPPED

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SPEEDOMETER-ODOMETER AND TACHOMETER

These instruments were mounted on a panel at the driver's left. The speedometer was driven by a cable from a worm gear arrangement on the final drive output shaft. The tachometer was driven by a cable from the right intake camshaft on the engine.

The speedometer was graduated from 0 to 132 km/hr. The odometer was capable of recording up to 99999.9 km and was at 00741.2 when received. This instrument was simple in design.

The tachometer appeared to be a very well-made instrument. It contained five instrument type ball bearings. It was graduated from 0 to 3000 revolutions per minute.

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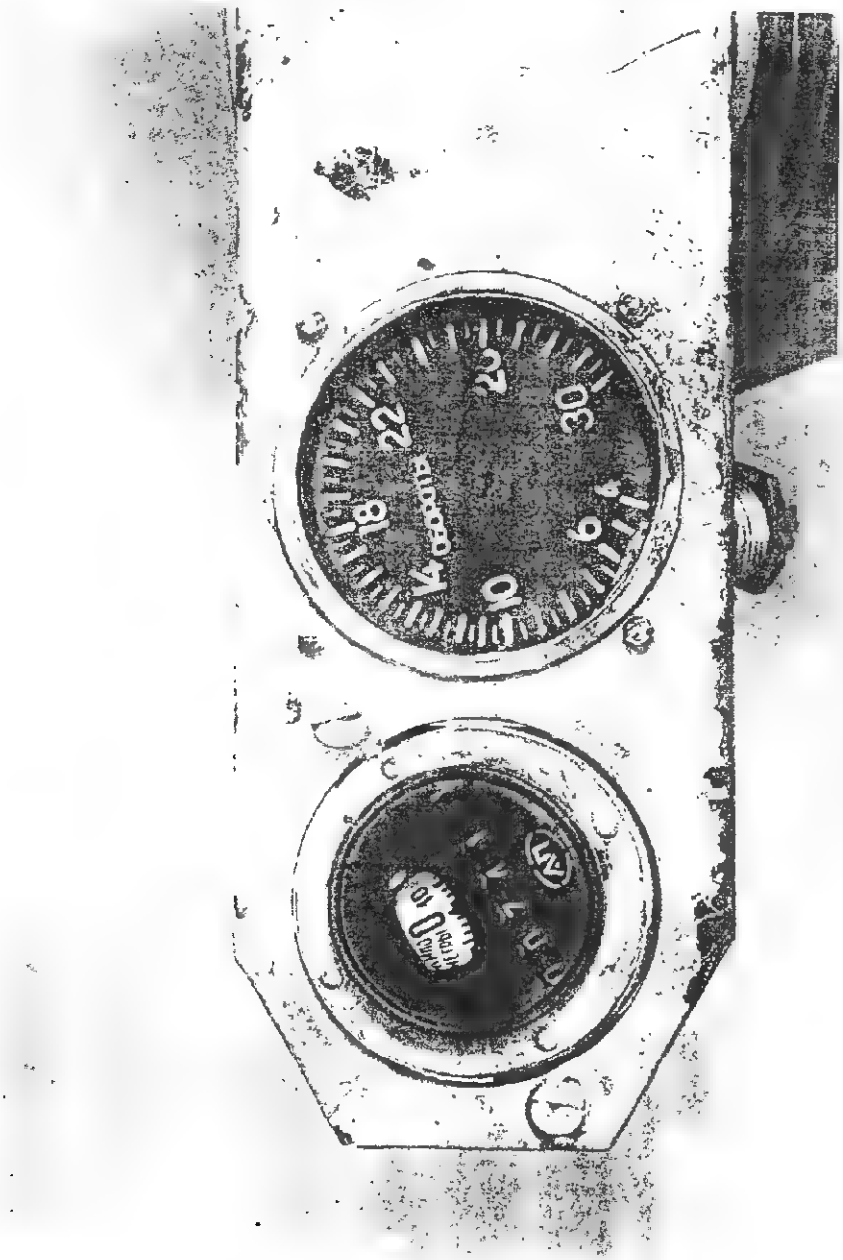

2206 - SPEEDOMETER AND TACHOMETER

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HULL ACCESSORIES
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2210.1 - GENERAL OPERATING INSTRUCTIONS AND STARTER ADJUSTMENT INSTRUCTIONS

The plate shown at the left was riveted to the fuel tank pressurization pump bracket in front of the driver. It contained general operating instructions and is interpreted as follows:

ATTENTION !

1. Depress main friction clutch quickly and completely. Release smoothly without jerking.
2. Engage reverse gear only after tank has stopped.
3. When tank has stopped on an incline, engage parking brake.
4. After each trip, inspect driving gear adjustment of:
   Main friction clutch.
   Transmission gear box.
   Side friction clutches and brakes.

The plate shown at the right was riveted to the bulkhead between the engine and the transmission and contains instructions for adjusting the starter pinion. It is interpreted as follows:

CHECK STARTER ADJUSTMENT

Adjusting it with the support.

(Starter pinion)

(Flywheel)

CLEARANCE

Front 4-4.5 mm. at height of 2 mm.

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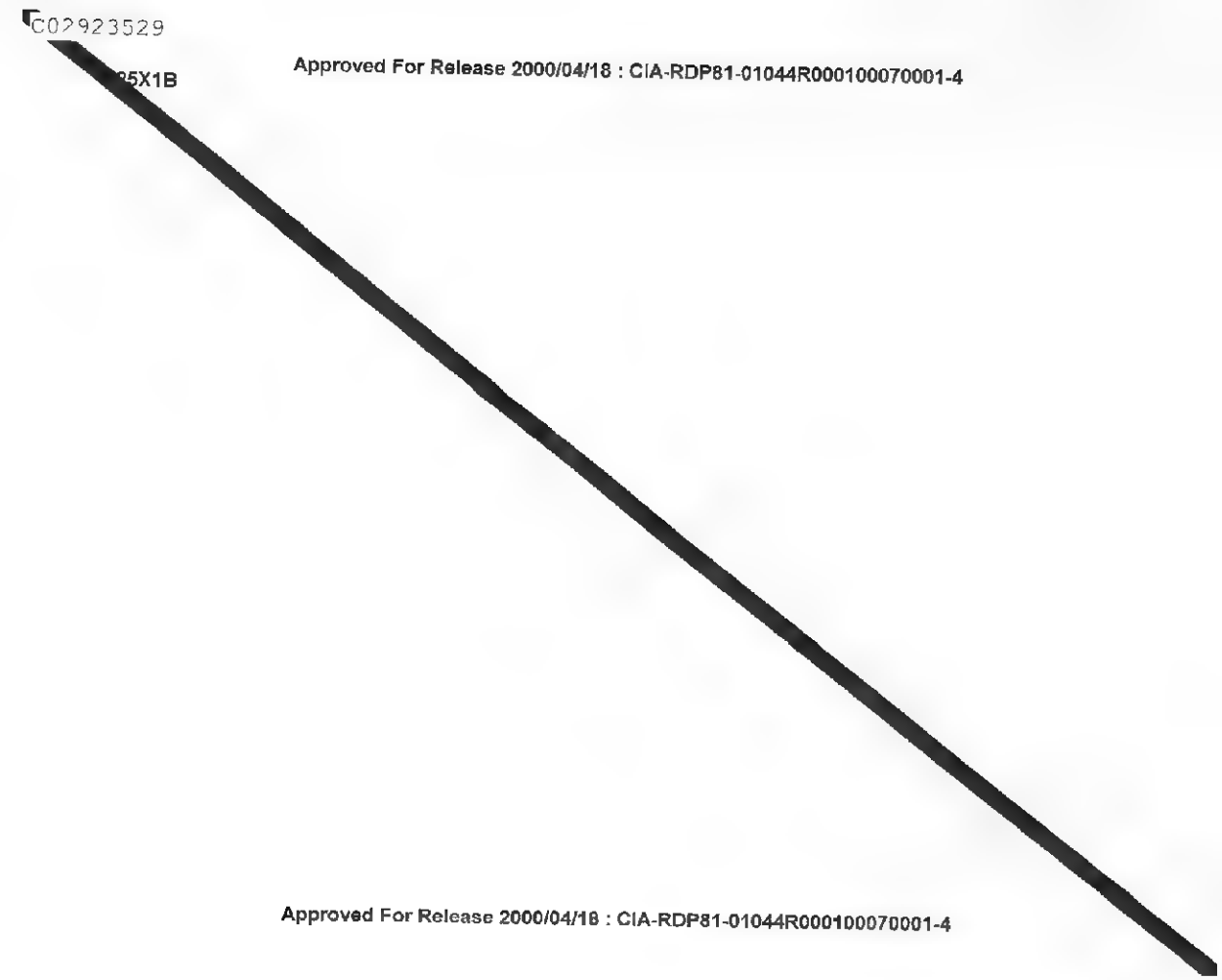

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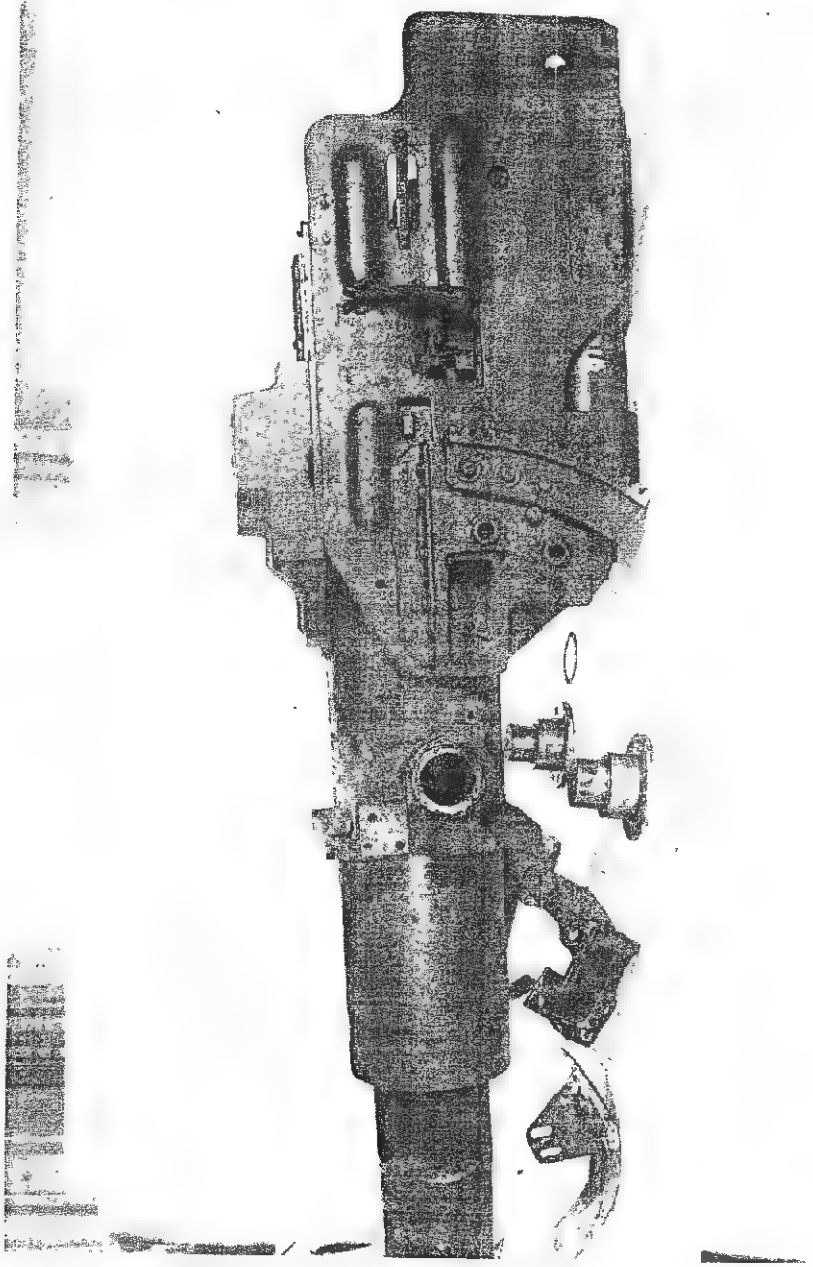

2701 - 85 mm GUN

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APPENDICES

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METALLURGY

Ferrous

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FERROUS METALLURGY REPORT

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CONCLUSIONS

High quality steels were obtained, especially so far as hardenability was concerned, by the generous use of alloying metals - chromium, nickel, and molybedenum, rather than through the use of more carbon. Materials that might have been regarded as critical seemed in ample supply. Their application represented intelligent rather than extravagant use, high strength and durability with minimum weight being the major consideration.

Three types of alloy steel were used for the armor: two for rolled plate and the third for cast members. The steel used for the thick plates had additional nickel and chromium for better hardenability - an excellent choice. Hardenability seemed adequate in all places checked.

The T34 armor had impact strength greater than that required by U. S. Army specifications yet exceeded our specification in hardness by as much as 100 points Brinell. This armor should have excellent penetrating resistance (for a given thickness) but might have been expected to spall. All armor had been quenched, probably in oil, except for the hull roof plate which was found dead soft. Chemically, the rolled armor was found to be moderately clean to very clean, the thicker plate being the better.

Ballistic joints such as those used at the front plates were commendable in relieving the weld metal at the joints of impact loads.

The transmission gear failures and the excessive wear on the final drive gears were regarded as lubrication failures that the use of "extreme pressure" lubricants could certainly have staved off. The Krupp steel used for all gears represented a high quality material for this application. Drawing had been done at too low a temperature, however, and the resulting surface brittleness had contributed to the failure.

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MATERIALS AND TEST PROCEDURE

Three welded joint sections were cut from the vehicle with a torch for metallurgical examination of rolled and cast armor and welded joints.

Location of the samples is shown in photographs 1800c, 1800d, and 1900.2c of the vehicle. The turret section was cut out on the right side (sighting along the gun) above the pistol port and included the roof weld. The bow section was cut out to the right of (facing the vehicle) and below the machine gun port and included the weld and portions of the upper and lower sloping plates. The section from the side was taken near the front on the right side and included the weld between the roof plate and sloping side plate. Each section was cut large enough with the torch so that samples could be machine cut away from the heat affected zone.

Figure 1. Bow joint between upper and lower sloping rolled homogeneous armor hull front plates, with the top plate resting in a groove cut into the lower plate. Outer and inner welds made with submerged arc process using ferritic electrodes.

The rolled homogeneous hull roof plate was attached to rolled homogeneous sloping side plate by single pass weld with manual arc process using stainless electrode.

The rolled homogeneous turret top plate was attached to turret sidewall casting by multi-pass weld made with ferritic weld metal.

Chemical analysis, hardness survey, macro etching and microscopic examination were made on each armor component in the three sections sampled. In addition, tensile and impact tests were made on the rolled and cast components of the turret. The weld metal deposits were subjected to chemical analysis and the adjacent areas were included in hardness survey, macro etching, and microscopic examination of the joints. Results of these tests are discussed in the following sections.

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TRANSVERSE SECTION THROUGH WELD JOINTS
X1-Picral HCl Etch

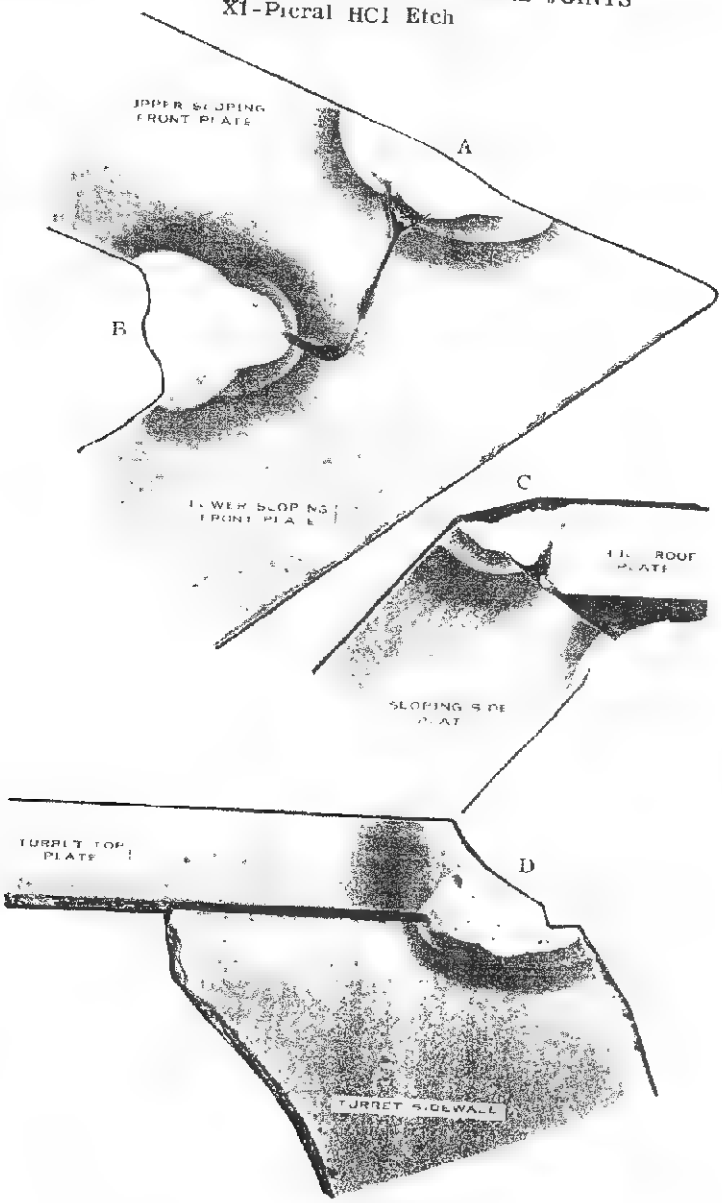

Figure 1

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DATA AND DISCUSSION

Armor

1 - Chemical Analysis

The analyses of the six armor components comprising the three welded sections, sampled, are included in Table I. Also included is the analysis of the casting for the final drive housing, which is the same composition as the turret casting but which retains a higher hardness. Three basic type analyses are evident, consisting of the following alloys:

a. Mn - Si - Ni - Cr - Mo

The sloping hull plates, 1-7/8 and 1-13/16 inches thick rolled homogeneous plates, are of this range of chemical composition:

C	Mn	Si	Ni	Cr	Mo
.23/.24	1.08/1.32	1.07/1.29	1.18/1.31	.86/1.04	.21

b. Mn - Si - Mo

The turret and hull roof plates, 13/16 inch thick rolled homogeneous plates, are within this range of analysis:

C	Mn	Si	Mo
.27/.31	1.22/1.42	1.35/1.36	.14/.19

Residual amounts of nickel and chromium are also present. This composition is similar in manganese, silicon and molybdenum content to that used for the thicker plates.

c. Si - Ni - Cr - Mo

The armor castings for the turret side wall and final drive housings are within these limits of chemical analysis:

C	Mn	Si	Ni	Cr	Mo
.23/.25	.83/.89	1.32/1.44	1.98/2.02	1.31/1.38	.18/.21

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TABLE I

ANALYSIS OF G812 TANK ARMOR

Part Name	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	(1951 Analysis) B.H.N.	Thickness
Turret - Top Plate	.27	1.22	.021	.025	1.36	.16	.21	.19	.15	413	13/16
Sidewall Casting	.23	.83	.021	.021	1.44	1.38	2.02	.21	.18	448	2-7/8
Hull - Roof Plate	.31	1.42	.024	.022	1.35	.06	.16	.14	.11	207	13/16
Sloping Front Plate - Upper	.23	1.32	.033	.013	1.07	1.04	1.31	.21	.22	444	1-7/8
Sloping Front Plate - Lower	.24	1.08	.022	.013	1.21	.94	1.18	.21	.22	418	1-13/16
Sloping Side Plate	.23	1.30	.032	.010	1.29	.86	1.27	.21	.59	444	1-13/16
Housing - Final Drive (casting)	.25	.89	.018	.019	1.32	1.31	1.98	.19	.21	460	2-1/8
										(1943 Analysis)	
Turret - Top	.36	1.33	.017	.022	1.59	.05	.14	.20	.12	495	
Sidewall	.26	1.30	.018	.010	1.37	.85	1.26	.195	.04	444-495	
Hull - Roof	.25	1.27	.018	.042	1.14	.10	.14	.195	.11	429	
Front - Upper	.23	1.20	.021	.026	1.10	1.05	1.26	.215	.09	430	
Front - Lower	.28	1.27	.023	.018	1.45	1.03	1.32	.22	.09	444	

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Note that this casting alloy is very similar to that used for the thicker rolled plate, differing only in having more nickel and chromium and less manganese.

2. Hardenability

End quench bars were machined from three of the Mn - Si - Ni - Cr - Mo rolled steel plates, one of the Mn - Si - Mo rolled steel plates and one of the Si - Ni - Cr - Mo cast steel components; all after annealing the sections of the hardened armor. The bars were austenitized for three hours at 1575°F. and end quenched according to the standard procedure. The hardenability curves are presented in Figures 2 and 3.

Sufficient hardenability is present in each of the alloys to quench harden the respective sections.

The armor components were heat treated by quenching, probably in oil, followed by tempering, with the exception of the hull roof plate which was not hardened. All of the armor sections examined contained high temperature transformation products except one 1-13/16" plate, which was hardened through.

The armor components were heat treated to a high hardness range of 413 to 460 Brinell. As pointed out in another section of this report, the hardness is considerably higher than American practice and was maintained to obtain maximum resistance to penetration at the possible sacrifice of structural stability on impact.

The rolled armor plate was judged to be very clean to moderately clean, with the thick side and front plates having better quality than the thinner roof plates. The thinner plates were cross-rolled, whereas the thicker plates were rolled in one direction only.

The general cleanliness of the turret casting appears to be good, in the section examined, except for the indication of inclusions as noted.

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664-5

25X1A

[redacted]

END QUENCH TEST

DATE 5-2-1951
OPERATOR
TYPE SPECIMEN STANDARD
TEST NO

TYPE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	AUST.	QUENCH TEMP °F
SLOPING SIDE PLATE	.23	1.30	.022	.010	1.29	1.27	.86	.21	.59	3 HRS.	1675°
TURRET SIDEWALL CASTING	.23	.83	.021	.021	1.44	2.02	1.38	21	.18	"	"
TURRET TOP PLATE	.27	1.22	.021	.025	1.36	.21	.16	.19	.15	"	"

REMARKS:

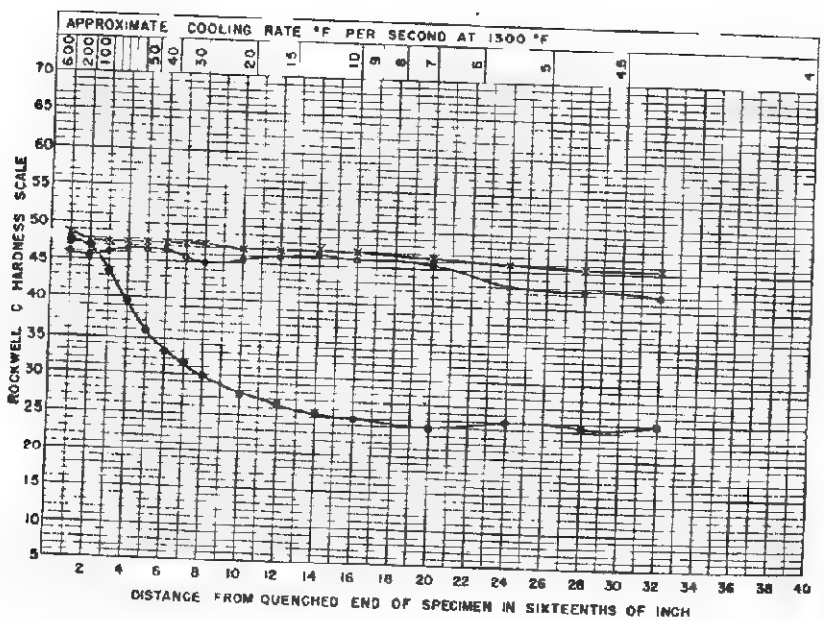

Figure 3

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[redacted]

END QUENCH TEST

DATE 5-2-1951
OPERATOR
TYPE SPECIMEN STANDARD
TEST NO

TYPE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	AUST.	QUENCH TEMP °F
FRONT PLATE UPPER	.23	1.32	.033	.013	1.07	1.31	1.04	.21	.22	3 HRS.	1675°
FRONT PLATE LOWER	.24	1.06	.022	.013	1.21	1.18	.94	.21	.22	"	"

REMARKS:

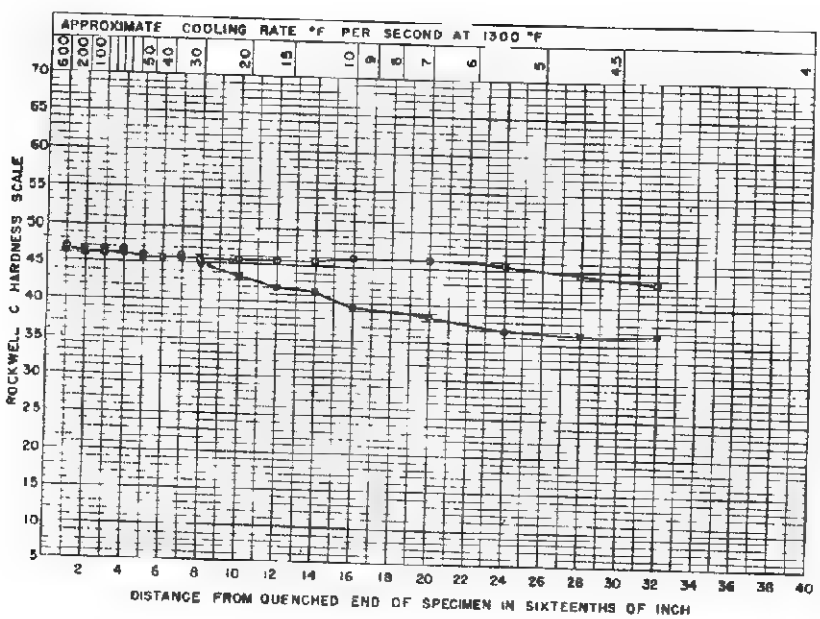

Figure 2

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3. Hardness Surveys

Rockwell "C" and Brinell hardness readings were made on cross sections of the armor containing the weld joints beyond the heat affected zones. The results of the hardness surveys are contained in Figure 4 and are summarized as follows:

HARDNESS SURVEYS OF RUSSIAN ARMOR

Armor Section	Thickness Inches	Hardness Range thru Cross Section Brinell	Rockwell "C"
Turret Top Plate	13/16	418	41-43
Turret Sidewall Casting	2-7/8	448	43-45
Hull - Roof Plate	13/16	207	12-13
Sloping Front Plate-Upper	1-7/8	418	41-43
Sloping Front Plate-Lower	1-13/16	387-418	41-46
Sloping Side Plate	1-13/16	444	44-46

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ROCKWELL "C" HARDNESS SURVEYS
OF CROSS SECTIONS OF RUSSIAN ARMOR

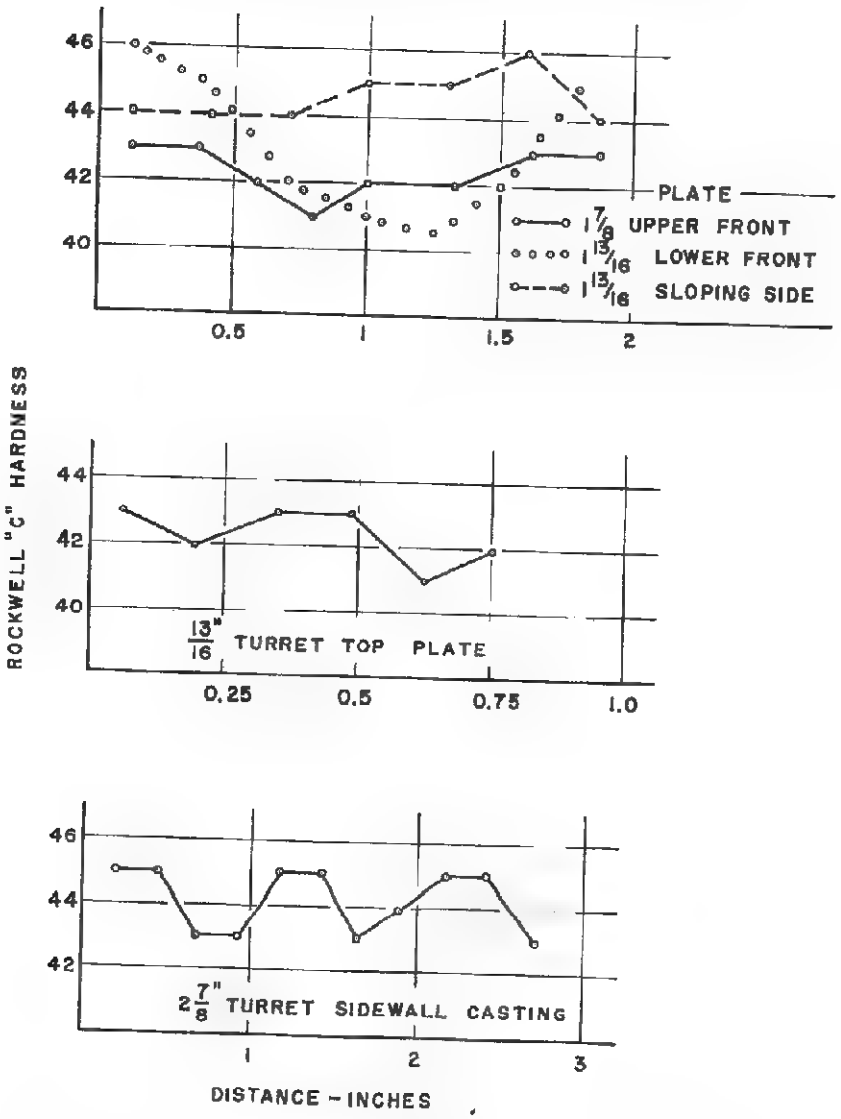

Figure 4

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4. Physical Properties

Physical tests were made on specimens from the turret top plate and sidewall casting. These components showed considerable change in composition from the 1943 Watertown Report, whereas the front and side hull plates were substantially the same and the physical tests were not repeated. The tensile test results are shown in Table II.

The strength and ductility of the rolled plate are satisfactory for the hardness and the transverse properties are only slightly below the longitudinal values. Due to casting defects and unsound metal, the side wall showed an absence of ductility and the strength was less than that expected for the hardness.

Impact tests were made on Standard Charpy V-notch bars at minus 40°F. The values are shown in Table II. The impact energy in ft. lbs. for the top plate is about equal in both directions and probably would be considered satisfactory for the hardness shown. The quality of the side wall casting has not influenced the impact results adversely and the impact energy in ft. lbs. in equal to or greater than the U. S. Army specification for cast armor at a lower hardness, although the Russian armor is 100 points higher in Brinell hardness.

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TABLE II

Physical Properties of Russian Armor

	YIELD STRENGTH 0.2 % OFFSET PSI	TENSILE STRENGTH PSI	ELONG. %	RED. OF AREA %	HARDNESS R "C"	REMARKS
Turret Top Plate, 13/16", Rolled, Homogeneous						
Longitudinal	161,100	205,700	10	36	45-47	1/2 cup fracture
Transverse	151,000	195,600	10	32	43	1/2 cup fracture
Turret Sidewall, 2-7/8" Cast Homogeneous						
Sample #1	184,700	195,900	1	-	45-47	Sample broken above gauge mark.
Sample #2	No yield, String curve	162,100	2	-	45-47	Surface defect.

V-Notch Charpy Impact Resistance - Ft. Lbs.

		Turret Top Plate
Longitudinal	1	10
	2	10
Transverse	1	11
	2	8

Turret Sidewall Casting	
1	15
2	15
3	18
4	13
5	16
6	15

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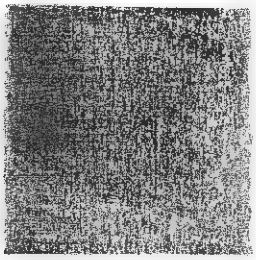
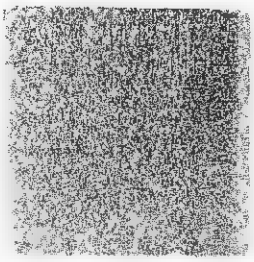
1-13/16" LOWER SLOPING FRONT PLATE (ROLLED HOMOGENEOUS ARMOR)

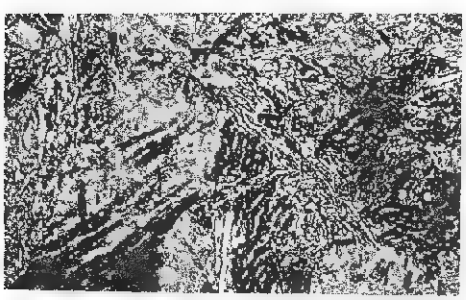


Longitudinal



Macroetch - X1 Transverse

X100 Unetched X100 Picral - HCl



X500 Picral - HCl

Figure 5

Macrostructure and Microstructure

Lower Sloping Front Plate

A moderately clean armor with typical inclusions shown in the unetched photomicrograph. The surface was mostly martensitic with increasing amounts of ferrite and transformation products toward the center. Material probably did not receive a good quench. Possibly tempered at a low temperature. Rolled only in one direction.

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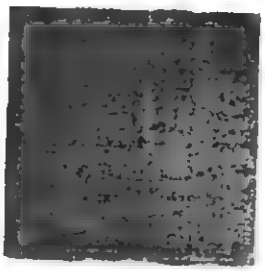
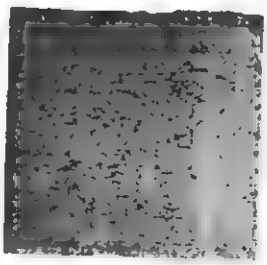
1-7/8" UPPER SLOPING FRONT PLATE (ROLLED HOMOGENEOUS ARMOR)

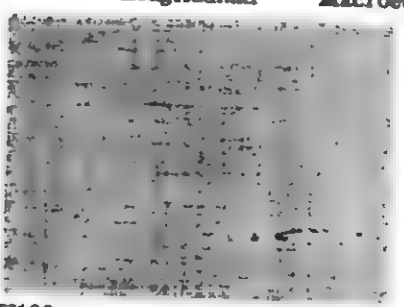


Longitudinal



Macroetch - X1

Transverse



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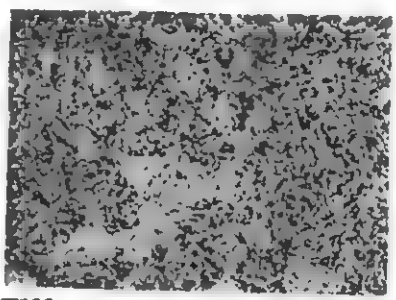
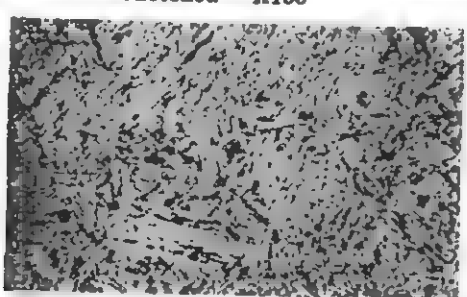


X100 Picral - HCl



X500 Picral - HCl

Figure 6

Macrostructure and Microstructure

Upper Sloping Front Plate

A moderately clean steel with typical inclusions shown in the photomicrograph. This material was completely martensitic from surface to center, indicating good solution and good quench. The material possibly had a low temper. Rolling appears to be in one direction only.

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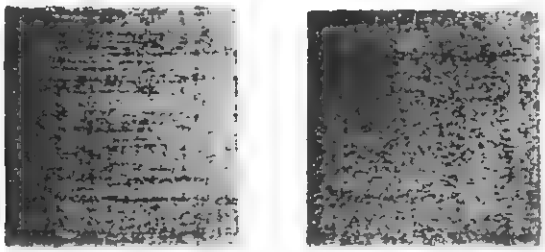
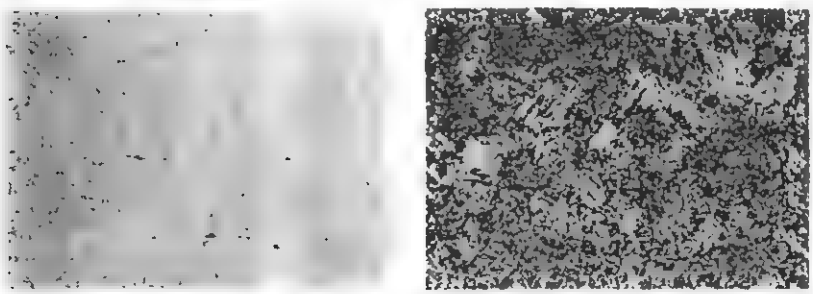
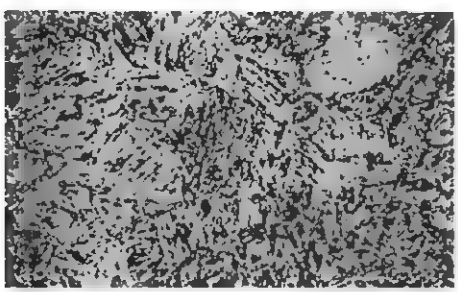
1-13/16" SLOPING SIDE PLATE (ROLLED HOMOGENEOUS ARMOR)



Longitudinal Macroetch - X1 Transverse



X100 Unetched X100 Picral - HCl



X500 Picral - HCl

Figure 7

Macrostructure and Microstructure

Sloping Side Plate

This armor was found to be very clean. Typical well scattered inclusions are shown in the unetched photomicrograph. Examination of the structure from the surface to the center showed it to be all martensite with a possible low temper, thus indicating good solution and a good quench. Rolling is in one direction only.

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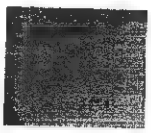
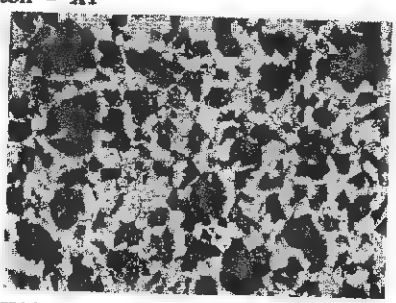
13/16" HULL ROOF PLATE (ROLLED HOMOGENEOUS ARMOR)



Longitudinal

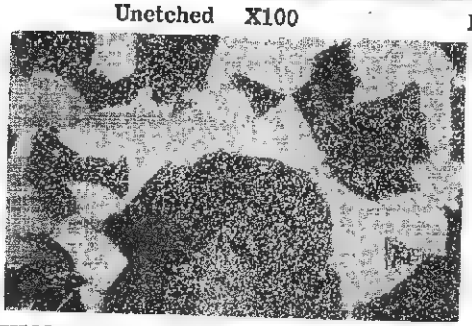
Transverse

Macroetch - X1



X100 Unetched

X100 Picral - Nital



X500 Picral - Nital

Figure 8

Macrostructure and Microstructure

This armor was moderately clean with typical inclusions shown in the unetched photomicrograph. This material was not hardened, but rather appears to be annealed or normalized followed by a high temper. Armor has been cross rolled.

The suspension cover plates, which fit into openings of the hull roof plate, are made of 13/16 inch rolled plate of the 0.24% carbon Mn - Si - Mo alloy composition and hardened to 444 Brinell.

Since the hull roof plate is covered by the turret it evidently was not considered necessary to harden it.

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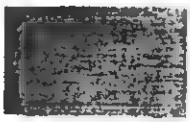
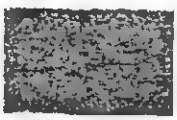
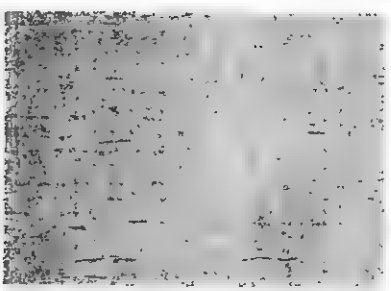
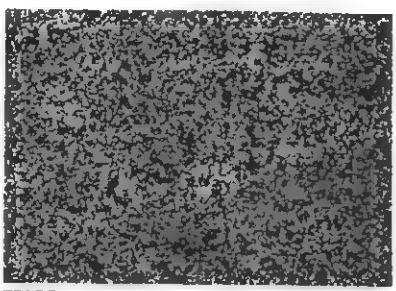
13/16" TURRET TOP PLATE (ROLLED HOMOGENEOUS ARMOR)

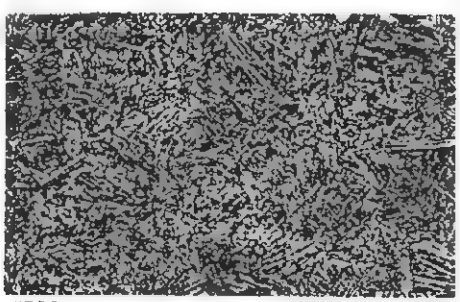
Longitudinal Macroetch - X1 Transverse



X100 Unetched



X100 Picral - Nital



X500 Picral - Nital

Figure 9

Macrostructure and Microstructure

Turret Top Plate

This material was not quite as clean as the other rolled armor. Typical inclusions are shown in the photomicrograph. The structure at the surface and center were about the same, martensite, ferrite, and some transformation products. Material possibly had a low temper. Armor was cross rolled.

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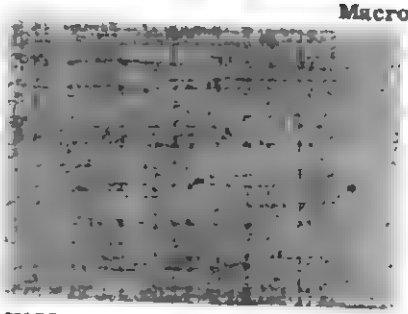
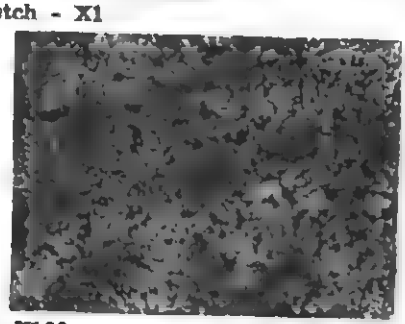
2-7/8" TURRET SIDEWALL (CAST HOMOGENEOUS ARMOR)

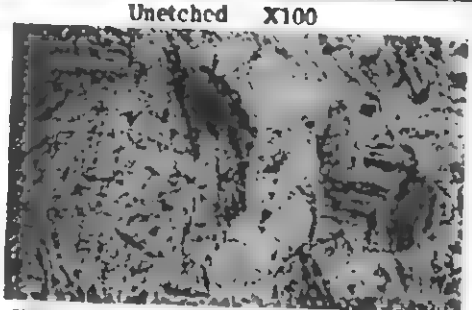
Macroetch - X1



X100 Unetched



X100 Picral - HCl



X500 Picral - HCl

Figure 10

Macrostructure and Microstructure

Turret Sidewall

The cast armor had small globular inclusions well dispersed through the matrix. The concentration was not heavy except in a few areas. A very large silicate inclusion was found in the sample examined and is shown in the photomacrograph. The surface was all martensite with transformation products being found near the core. Material possibly had a low temper.

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WELDING AND JOINT DESIGN

1. Visual Examination

There are only two ballistic type joints used on the hull. The top sloping front plate is joined to the top sloping side plate with a double V joint, single groove weld. This is the closest approach to a ballistic type joint on the hull. The bow is formed by a ballistic type single bevel joint with the top sloping front plate resting in a groove cut into the lower sloping front plate.

The others in front are lap joints, having a partial overlap with fillet weld.

A previous report on a T34 tank by Watertown Arsenal Laboratory notes the "rough flame cutting of armor and crude fitting where there is no requirement for better workmanship". This is evidenced on the present tank by grinding on corners of the driver's hatch opening, which shows lack of skill in flame cutting thru the front plate. Openings in the side wall for the suspension arm are flame cut. The cut is started by hand at the edge of the plate and machine cut above.

The armor plate forming the hull is torch cut and welded.

Manual welding on the hull is characterized by great roughness.

The exterior hull welds of armor plate are austenitic with the exception of the automatic weld across the bow which is ferritic.

The sloping side plate is lapped over the horizontal side plate and is secured inside the hull with occasional hand tack welds 4" long about 18" apart. The horizontal side plate partially overlaps the side wall and has a machine made, ferritic fillet weld. The floor to side plate is a manual, ferritic, fillet, lap weld with no mechanical features and incompletely fused. One weld is inside the wall and another on the bottom of the hull. The front floor is thicker than the rear, the split coming at the bulkhead.

Welds of brackets on the hull show numerous cracks. Bumper brackets and suspension mountings on the side of the hull are ferritic.

The final drive housing (casting) has supplemental rivets through the side wall in addition to hand welding. There are no resistance welds on hull or turret attachments.

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The engine hatch is flame cut, probably with the help of a template, with hinges welded. The hatch frame is hot-formed (pressed or drawn) from rolled plate.

The sloping plate over the transmission compartment is flame cut from rolled plate. Overlapping covers for the exhaust manifold are hot formed from plate and bolted on.

The circular center door is flame cut from plate on a bevel and the disc is machined on the cut edge. The door hinge is manually welded by ferritic electrode.

Two or more cracks in the rear sloping plate are repaired using stainless electrodes.

The turret support ring is welded to the roof plate with bare rod and coated rod; part is automatic and part ferritic. This ring is machine turned after weld. It appears to have one fourth the strength of the ring used in the American tank and is so light, warpage necessitated shims to line up the turret so it will swing. Thin tin plate shims are placed under the turret ring.

Reinforcements are welded at the top of the sloping wall of the hull on two sides and the front using austenitic deposit.

Welding on Intake and Exhaust Manifolds

Two stampings are edge welded using gas. The port plates are arc welded.

2. Chemical Analysis

Results of chemical analysis of drillings taken from weld deposits of three joints are given in Table III.

One type of ferritic electrode was used in the joints analyzed. The carbon range is the same or slightly lower than American practice. The silicon is two to three times that used here. The manganese appears to be reduced in the turret roof weld. The chromium and nickel content may have been added to strengthen the weld, but could be residuals in the steel wire plus pick up from the armor plate.

There is no modification of the approximate 18-8 austenitic analysis, used for the hull roof weld, by the addition of either manganese or molybdenum to stabilize the austenite in the weld metal.

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TABLE III

CHEMICAL ANALYSIS OF WELD METAL DEPOSITS

	C	Mn	Si	Ni	Cr	Mo
Turret - Roof to Sidewall	.10	.71	.86	.59	.41	.08
Hull - Roof to side plate	.17	.70	.49	10.00	17.94	.07
Hull - Bow Weld - Outside	.10	1.00	1.10	.54	.37	.09
Hull - Bow Weld - Inside - Top	.11	.97	.99	.50	.30	.08
Hull - Bow Weld - Inside - Bottom	.12	1.05	1.00	.60	.42	.09

3. Hardness Surveys

Vickers - Brinell hardness surveys of weld deposits and weld-heat-affected zones of base metals taken on three joints are summarized in Table IV.

The weld metal hardness is low (Brinell 179-279) in the austenitic and three other ferritic deposits.

The heat affected zone adjacent to the austenitic weld has been reduced in hardness from that of the base metal due to the limited quench effect of the plate corner. This is also true of the ferritic weld to the Mn - Si - Mo plate where low alloy is a factor together with the location at the corner of a narrow plate. The zones at the root of the other ferritic welds are lowered in hardness due to the tempering effect of the overlaying welds. There is an increase in hardness accompanied by cracking in the upper sloping front plate where the welding heat has been dissipated rapidly.

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TABLE IV

SUMMARY OF HARDNESS* SURVEY ON WELDED JOINTS

	Weld Metal	Weld Heat Affected Zone	Tempered Zone	Base Metal
Traverse A	Crown 187	Turret Top Plate 258-294-279-264-279 294-286-264-253	258-286-327-353-390	418
Traverse B	Crown 179-183 Body 207-212 Root 219-219-219-231-264	Turret Sidewall Casting 390-400-390	294-301-336-371-409 432	448
Traverse C	Crown 179-187 Body 237-203-203-203	Turret Sidewall Casting 353-336-353-362 327-319	301-327-344-381 409-432	
Traverse A	Austenitic 219-203-187-171-226	Sloping Side Plate 400-390-409-421-421-432-432-353	311-319-336-344-353-371-390-400-409-421-432-443-481	444
Traverse A	Crown 243-212- and Body 203-194	Sloping Front Plate - Upper 432-443-443-432-400	311-301-311-327-336-371-400-421	418
Traverse B	Crown 219-203-219 and Body -226	Sloping Front Plate - Lower 226-219-243-264-226-219-212	353-362-371-381-381-336-327-353-409-421	387
Traverse C	Crown 279-237-226-212-212	Sloping Front Plate - Upper 469-455-455-409	336-311-311-319-353-381-400-421	418

* - Converted from Vickers Brinell to Standard Brinell

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4. Macro Examination

Macroetched sections through the weld deposits were photographed and then hardness traverses made through the joints. See Figures 1 and 11.

Turret Top Plate

Multi-pass weld composed of at least three beads. Top pass is automatic submerged arc. Underneath passes are also thought to be submerged arc as indicated by good penetration. Slag pockets present with intergranular cracking extending toward surface. Penetration and fusion is satisfactory as it was with other multipass welds. Hardness traverse across the weld interface showed variations in hardness from R"C" 18 in the weld metal, from R"C" 36 to R"C" 43 in the portion of heat affected zone that exceeded the critical, and from R"C" 30 to R"C" 44 in the area where the heat affected zone blends into the unaffected armor. No use was made of annealing bead technique.

Side Plate to Roof

Single pass weld made with manual arc process using stainless electrode. Very incomplete fusion. Fusion extends half way to bottom of groove.

Crack in weld metal result of wide shallow weld bead. Hardness readings in stainless weld vary from R"C" 6 to 18. The heat affected zone was R"C" 38 to R"C" 46 where it exceeded the critical temperature and R"C" 33 to R"C" 50 as this zone blends into the unaffected metal.

Bow - Outside Weld

Single pass submerged arc process weld made with ferritic weld metal. Even with excellent penetration of submerged arc process, fusion penetrated only 2/3 of depth of groove. Very wide weld on top of 60° groove suggests slow travel speed. Underbead crack extends from bottom of weld to within 1/3 of top.

Bow - Inside Weld

Same as above except two pass weld used. No cracks are evident and penetration is good.

Hardness readings in the weld deposit were from R"C" 12 to R"C" 29. The zone heated above the critical ranged from R"C" 38 to R"C" 49, and from R"C" 32 to 45 in the slightly affected zone.

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PHOTOGRAPHS OF WELD JOINTS
X2-Picral HCl Etch

Figure 11

Transverse Section Through Weld Joints

WELD A - Single pass weld. Poor penetration at base. Cracks in heat affected zone of base metal. Fusion good. Structure is scattered pearlite and small carbides in a dendritic ferrite matrix.

WELD B - Double pass weld. Excellent penetration and fusion. Dendritic ferrite matrix with scattered pearlite and small carbides.

WELD C - Single pass weld. Poor penetration. Fusion good. Structure of weld is austenitic.

WELD D - Triple pass weld. Penetration and fusion are very good. Evidence of incomplete scale removal before finish pass was made. Several cracks visible in the welds. Structure is scattered pearlite and small carbides in a dendritic ferrite matrix.

PHOTOMICROGRAPHS OF WELD JOINTS
X100-Picral Nital Etch

Figure 12

Microexamination

Photomicrographs 1 and 2 were taken of weld A which was also the typical structure of welds B and D. The weld metal structure consists of scattered pearlite and small carbides in a dendritic ferrite matrix. Photomicrograph 1 shows cracks formed between the weld and base metals, while photomicrograph 2 illustrates a perfectly sound weld. Weld C is austenitic with good fusion as shown in photomicrograph 3.

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PHOTOGRAPHS OF WELD JOINTS
X2-Picral HCl Etch

UPPER SLOPING FRONT PLATE

A

LOWER SLOPING FRONT PLATE

UPPER SLOPING FRONT PLATE

B

LOWER SLOPING FRONT PLATE

HULL ROOF PLATE

C

SLOPING SIDE PLATE

TURRET TOP PLATE

D

TURRET SIDEWALL

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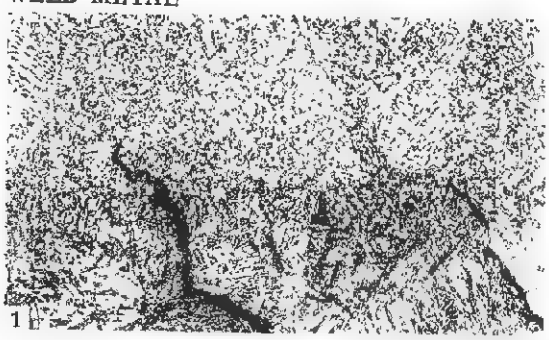
PHOTOMICROGRAPHS OF WELD JOINTS
X100-Picral Nital Etch

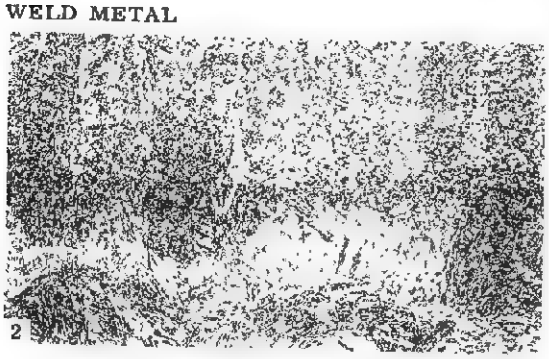
WELD METAL



1

BASE METAL

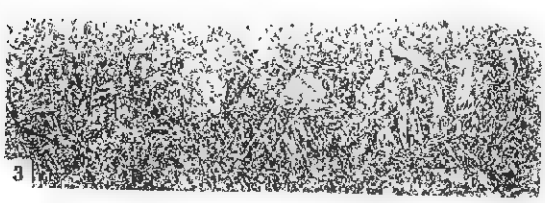
WELD METAL



2

BASE METAL

WELD METAL



3

BASE METAL

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HULL WELDING

Front:

All frontal welds are protected, to a degree, from penetration by the overhang of the plate and by the machine gun port casting and also by the angularity at the bow weld.

The top sloping front plate to top sloping side plate welds are fully protected by this overhand. The top and bottom sloping front plates to lower side plate welds are protected by partial overhang.

The bow joint between the top and bottom sloping front plates is made by a multiple pass submerged arc weld. The material is a ferritic deposit.

The brackets and attachments on the front plate have rough manual welds with austenitic weld metal. The bosses to receive the spare track attaching screws have excessive welding material in comparison with the amount of welding on the lifting shackle.

The casting for the bow machine gun mount spans the opening in the sloping front plate affording no direct path for penetration through the weld. This joint is a manual pass weld using austenitic material.

The corresponding bow gun casting used on American World War II tanks was welded flush with the bow plate, producing a strained weld which cracked frequently during welding or on subsequent exposure to cold weather.

Hull weld joining upper front plate, upper side plate, and top plate: (See photograph 1800.2)

The front weld is a manual austenitic deposit made in the horizontal position. Flat positioning would have greatly improved this weld. Uneven pattern and lack of fill at the top indicate a low order of skill. Inside weld at this joint is made in overhead position and is rougher than the outside weld. It became even rougher when the operator had to reach into the boxed-in corner. The hull roof plate to hull sloping side wall joint shown in this view has the appearance of a machine weld. This portion is 20 inches long extending from the right front of the roof. The balance of the roof weld which extends to the bulkhead is manual. Both of these deposits are austenitic.

Weld joining the idler wheel arm housing to the hull side plate: (See photograph 1800.4a)

The idler wheel arm housings were manually welded on the hull side plates prior to the fabrication of the side plate and hull. Ferritic welding electrode was used. The side plate to top sloping front plate welds were made using stainless steel electrodes.

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The welding was done as the plates would stand in their normal position. The welds were made on the flame-cut surfaces, without cleaning. The very bumpy weld beads are manual deposits and suggest a low order of operator skill.

Weld joining upper front plate to left side plate and repair weld on front plate: (See photograph 1800.3)

The view shown in the accompanying photograph is of the inner corner of the front and side intersection welds. The manual welding is very rough, probably the result of poor welding technique or inadequate electrodes or both. The welding was done in a horizontal position indicating very little attempt to accomodate welding by proper positioning or design of joints. The deposit is austenitic.

The weld in the top plate and side plate extending across the joint was undoubtedly made to repair a crack developed after some service. Rivets were placed at the ends of the crack which was torch cut and filled with weld metal using a straight side slot weld. The weld was manual and the deposit is austenitic.

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TURRET WELDING

Weld joining turret top plate to side casting and repair weld on side casting: (See photograph 1900.4)

The roof joint is formed by overlap of the top plate on the turret side wall casting. There was no welding inside the turret at this joint. The straight portions are welded with ferritic electrode automatically deposited by submerged arc process (Union Melt), using dual passes. The corners are manually welded with ferritic electrode laid over the automatic weld. The portion of the roof joint on the side over the cannon (not shown in this view) has a manual, horizontal, multiple pass, built up fillet weld with austenitic deposit. This weld was not positioned and is very rough and has heavy undercut. There is high splatter inside the turret. The reasons for the use of different methods of welding the roof joint are not apparent. It is possible that the curved sections and the portion of the joint over the cannon were not accessible to the welding machine or it was due to rough casting. The ventilating port shield is made of hot formed, hot rolled plate welded to the top plate with ferritic electrode, manually deposited. The ring surrounding the entrance hatch and other attachments have manual ferritic welds. The commander's hatch casting is welded to the top plate with ferritic electrode, automatically deposited, by the submerged arc process. (The upper portion of the casting, only, is shown in this view.) The large weld in the corner of the turret casting near the roof is a manual austenitic deposit made to repair a long crack probably resulting from welding stresses. Rivets at each end of the repair are used to prevent propagation of the crack during welding. The lifting hooks are manually welded to the turret casting with ferritic electrodes. Other brackets and attachments to the turret casting have manual austenitic deposits. All welds appear to have been made with the turret resting on the bottom without any attempt to position parts to accomodate welding.

Two welds are used for the turret support ring to the turret casting. The lower weld (toward edge of casting) is a ferritic weld made by the automatic submerged arc process. The weld of the upper side of the support ring is also ferritic and is made in two passes, manually. These welds show heavy undercut.

The turret bearing race is fastened to the support ring with flat head screws.

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Turret Bearing Race Ring

The turret ring (hull side) was made of high carbon, low alloy steel of no comparable American specification. The analysis is:

C	0.59%	Si	0.30%
Mn	0.90	Cr	0.24
P	0.019	Ni	0.50
S	0.015	Mo	0.07

The ring was used as hot rolled with no heat treatment of the gear teeth or ball race after machining.

Hardness Test:

Surface of gear teeth	Rockwell "C" 22 to 24
Surface of race	Rockwell "C" 22 to 24
Core of ring	Brinell 241

Microstructure:

Dense pearlite and small amount of ferrite in grain boundaries

Turret Bearing Balls

The turret bearing balls were made of high carbon chromium steel, hardened through, of the approximate composition F.S. - E52100

The analysis is:

C	0.98%	Si	0.27%
Mn	0.43	Cr	1.57
P	0.016	Ni	0.36
S	0.013	Mn	0.07

Hardness Test

Surface - Rockwell "C" 64-66
Core - Rockwell "C" 63-64

Microstructure:

Fine spheroids of carbides and a fine carbide network in the grain boundaries in a martensite matrix, possibly low temper.

Final Drive Inner Housing

The inner housing is a steel casting, welded to the hull, of a medium carbon, chromium, nickel, composition for which there is no exact American specification. The analysis is shown below:

C	0.33%	Si	0.34%
Mn	0.76	Cr	0.65
P	0.24	Ni	0.78
S	0.22	Mo	0.08

Hardness Test:

Surface of casting - Brinell 212

This hardness value indicates there has been no attempt to improve the physical properties of the casting by heat treatment.

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SUSPENSION AND PROPULSION COMPONENTS

1. Three principal grades of wrought alloy steel were used. In addition, a dozen or more different grades were used for individual applications for specialized parts.

   a. Krupp-type Ni - Cr - Mo steel. Used as carburized and hardened for transmission gears, oil pump drive shaft, generator drive shafts, crankshaft gear, final drive gear and pinion. Used as quenched and tempered for transmission main shaft, countershaft, and reverse idler shaft; crankshaft; connecting rods and bearing caps; studs-cylinder head, main bearing cap, connecting rod cap; main bearing through rod; intake valve; final drive shafts.

   b. 3/4% Cr - 3.0% Ni. Used as carburized and hardened for piston and link rod pins; valve adjusting screws; water pump shaft; accessory gears.

   c. 1.50% Cr-1.30% Si-0.25% Ni. Used as quenched and tempered for valve adjusting screw lock ring; screw - rod pin retainer; oil pump gear; track drive wheel roller and pin; track adjusting worm and gear; track pin; gearshift rail; gearshift fork; suspension arm forgings.

2. Steel castings were of one grade corresponding approximately to SAE 8635. Used for track drive wheel, rectangular suspension arm, inner final drive housing.

3. Chemical Analysis

	C	Mn	Si	Cr	Ni	Mo
Krupp	.13/.24	.33/.49	.15/.40	1.27/1.80	3.21/4.50	.07/.34
Cr-Ni	.11/.22	.30/.46	.20/.39	.71/1.08	2.42/3.24	.03/.12
Cr-Si-Ni	.33/.42	.37/.63	.96/1.39	1.34/1.75	.07/.41	.02/.13

Analysis of other grades, which correspond closely to specification, are shown later in the data and discussion of individual parts.

The Krupp analysis was used in the highly stressed parts of the engine, transmission, and final drive where response to quenching in large sections was a factor. The engaging ends of the clash gears were chipped and battered in service. This condition could have been aggravated by the tendency of Krupp steels to form a carbide network around the grain boundaries on slow cooling after carburizing. These carbides are extremely difficult to redissolve on subsequent heating and produce a brittle case on hardening the gears.

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The through hardening properties of the quenched and tempered parts were obtained by using the same Krupp analysis as for the carburized parts. The low carbon and manganese content was the same and the alloy content provided the hardness. Case depths generally followed our practice, though on the transmission gears it was unusually great.

For the lighter carburized parts, the chromium and nickel contents are reduced to the approximate composition of the SAE 3400 series.

The lighter quenched and drawn parts and the suspension arm forgings, which are heat treated to a lower hardness than parts with the Krupp analysis, are made of a medium carbon chromium silicon alloy steel. There is no similar composition used in this country.

In the selection of compositions for the wrought steels used in this vehicle, the Russians have made no use of higher manganese content to increase hardenability. This element is not considered to be in short supply in their country. Also, the carbon content is not raised in the Krupp analysis to increase the hardness of the quenched and drawn parts. Any adjustment for this purpose appears to be in raising the alloy content, and thereby obtaining greater toughness for a given hardness.

The transmission drive gear and pinion are spiral bevel and show normal wear of the teeth surfaces with the bearing heavier toward the toe on both drive and reverse sides. The other gears in the transmission have spur teeth and all show a great amount of wear on the tooth surfaces such that grooves have been formed at the pitch line or below. Surface failures have occurred in the case so that metal has separated and caused pitting in the teeth. As noted in the report of the lubricant, taken from the transmission case, there were no extreme pressure additives used. While the lubricant was adequate for the spiral bevel gear and pinion, it did not withstand the pressure between the spur teeth and wear and fatigue failure of the tooth surfaces resulted. The case depth and core hardness of the carburized parts are satisfactory; however, it is possible that the gears were box cooled from the carburizing temperature and then reheated for hardening at insufficient temperature to put the excess carbides in solution. The practice employed for Krupp steel by a manufacturer of heavy duty gears in this city was to box quench from the carburizing temperature, reheat at 1500°F. quench and temper for a martensitic structure, free from carbides and austenite.

The transmission and final drive gears have the rim and most of the web carburized and hardened. The splined hub is not fully hardened. It is not determined how much warpage of the gears and distortion of the tooth form influenced the wear on these parts but it may have been considerable.

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FERROUS ENGINE PARTS

Crankshaft:

The crankshaft was forged quite close to size from Krupp steel. It was machined all over and polished after heat treatment. The analysis is shown in Table V. Heat treatment was uniform throughout with no surface hardening of the main bearing or crank pin surfaces.

Hardness Tests

Cheek surface	BHN 375
Main bearing	BHN 375, R"C" 35-37
Main bearing core	BHN 375
Crank pin surface	BHN 364, R"C" 35-37

Scleroscope Readings on Bearing Surfaces

No.	Main	Rod
1	48	50
2	50	50
3	50	50
4	50	48
5	48	50
6	50	50
7 next	50	
end	48	

Profilometer Readings of Surfaces

Rod and Main Bearing	20-25 microinches
Fillet, Rod and Main Bearing	25-30 microinches

Microstructure:

The structure is uniform from surface to core and is the same for both crank pin and main bearing. It consists of tempered martensite with no evidence of surface hardening.

Master Connecting Rod

The connecting rod was forged from Krupp steel and was machined all over and polished after heat treatment. The analysis is shown in Table V.

The hardness on the part was BHN 340 obtained on the flange, midway way of the length. The connecting rods were heavily marked on the flange outside at the lower end with an electric pencil. There was a stamped inspection mark at the pin boss on the edge of the flange.

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Link Rod

The link rod was forged from Krupp steel and was machined all over and polished after heat treatment. The analysis is shown in Table V.

The hardness on the part was BHN 351 obtained on the flange, midway of the length. The link rods were marked on the flange with an electric pencil. There was a Russian Brinell impression midway on the web section.

Connecting Rod Bearing Cap.

The bearing cap was forged from Krupp steel and was machined all over and polished after heat treatment. The analysis is shown in Table V.

The surface hardness was Rockwell "C" 36-37.

Piston Pin

The piston pin was machined from nickel chromium steel, carburized and hardened. The analysis is shown in Table V.

Hardness Tests:

Surface	Rockwell "C"	59-60
Core	Rockwell "C"	29-32

Profilometer Readings of Surfaces

#A Pin	O.D.	3-1/2 - 4	Microinches
	I.D. center	30-65,45-65	Microinches
#B Pin	O.D.	2-1/2 - 3	Microinches
	I.D. center	40-60	Microinches

Microstructure:

O.D. case depth 0.040". No case in the bore.

Case - Excess carbides and martensite. Some of the carbides are quite large and spheroidized in the grain boundaries.

Core - Acicular ferrite, low carbon martensite and transformation products.

The part apparently was reheated after carburizing for hardening.

Link Rod Pin

The wrist pin was machined from nickel chromium steel, carburized and hardened. The analysis is show in Table V.

Hardness Tests:

Surface	Rockwell "C"	63
Core	Rockwell "C"	32

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Microstructure:

O.D. case depth - 0.048-0.052". No case in the I.D.

Case - Martensite with a definite grain boundary. Indicates a reheat treatment.

Core - Acicular ferrite, transformation products and some low carbon martensite.

Link Rod Pin Retainer Screw

The retainer screw was upset from medium carbon chromium silicon steel to form the head. The analysis is shown in Table V. It was machined after heat treatment which hardened it through.

Hardness test: Rockwell "C" 24.

Microstructure: Quenched and tempered martensite.

Link Rod Pin Retainer Screw Washer

The washer was stamped from 0.011" brass shim stock of the following composition:

Cu	62.9%	Fe	Trace
Sn	Nil	Ni	Trace
Pb	Nil	Zn	Balance

This composition is similar to an alpha brass with approximately 2 and 1 alloy composition.

Physical Properties: Bergsman value of VHN 129 or BHN 114 or Rockwell "B" 72. Microstructure is typical for wrought alpha brass. No impurities noted in structure.

Studs

The highly stressed engine studs and through rod were made of Krupp steel heat treated to a hardness of Rockwell "C" 30-35. The analyses of the parts are shown in Table V.

Cylinder Head Stud

Surface hardness of the stud is Rockwell "C" 33-35. The threads are cut. The coating on the studs is iron oxide, probably from the heat treatment.

Main Bearing Cap Stud

Surface hardness of the stud is Rockwell "C" 33-35. The threads are cut. The coating on the studs is iron oxide, probably from the heat treatment.

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Connecting Rod Bearing Cap Stud

The studs were machined from heat treated bar stock and have the same cut thread on both ends. The shank was ground on centers.

Surface hardness on some of the studs is:

1 - R"C" 33-35	4 - R"C" 33-36
2 - R"C" 28-33	5 - R"C" 33-35
3 - R"C" 32-34	

Crankshaft Main Bearing Cap Through Rod

Surface hardness of the through rods is Rockwell "C" 30-33. The threads are cut. The coating on the rods is iron oxide, probably from the heat treatment.

Cylinder Head Stud Nut

The nuts were machined from a medium carbon chromium nickel steel and heat treated. The analysis is shown in Table V. Hardness Rockwell "C" 25-28 and 28-32. The nuts were cadmium plated and unbuffed. The depth of plate is 0.00014".

Cylinder Head Stud Nut Washer

The washers were made of plain carbon spring steel hardened to Rockwell "C" 40-43 and 43-44. The analysis is shown in Table V. The washers were cadmium plated. The depth of plate is 0.00014".

Main Bearing Cap Stud Nut

The nuts were machined from a medium carbon chromium nickel steel and heat treated. The analysis is shown in Table V. Hardness Rockwell "C" 24-27. The nuts were cadmium plated and unbuffed. The depth of plate is 0.00014".

Connecting Rod Bearing Cap Stud Nut

The nuts were machined all over from heat treated Krupp steel. The analysis is shown in Table V. Hardness on some of the nuts is:

No. 1	Rockwell "C" 37	No. 30	Rockwell "C" 36
2	35	31	37
11	36	33	37
21	37	36	37

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Crankshaft Main Bearing Cap Thru Rod Nuts

The nuts are machined from a medium carbon plain carbon steel. The analysis is shown in Table V. The hardness of both the plain nuts and lock nuts is Rockwell "C" 20-24. The coating on the nuts is an iron oxide, probably heat treat scale.

Main Bearing Thru Rod Washer

The washers were rough stamped from 1/16" thick brass sheet stock of the following composition:

Cu	61.6%	Fe	Trace
Sn	Nil	Ni	Trace
Pb	Nil	Zn	Balance

This composition is similar to alpha brass or Muntz metal.

Wide variation in hardness values is noted as follows:

#1 Rockwell "B" 45-46	#3 Rockwell "B" 31
2 Rockwell "B" 45-47	4 Rockwell "B" 32-36

Microstructure is normal alpha brass structure. Severe cold work was noted at wear adjacent to I.D. and O.D. of washer.

Cylinder Liner

The liner was made of steel tubing of composition corresponding to Nitralloy G or its modification for aircraft. The analysis is shown in Table V. The bore side only was nitrided. Flow lines show the liner was machined from straight tubing with no upset at the rim. Results of a Vickers hardness traverse spaced along the bore beginning at the top are shown below. The hardness is considerably lower than can be obtained by nitriding.

Vickers Brinnell 5 Kg. Load	Converted to Rockwell "C"
713	63
689	62
701	63
701	63
713	63
701	63
713	63
689	62
689	62
713	63

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Vickers Brinell 5 Kg. Load	Converted to Rockwell "C"
701	63
713	63
689	62
713	63
689	62
677	61.5
677	61.5
689	62
701	63

Core of the liner - Rockwell "C" 31.
Micro examination - Nitrided surface - depth 0.015". Case - coarse, grain size 4 to 7.
Structure of core tempered martensite.
The wet side of the liner had been plated with zinc to protect it from corrosion.

Piston Ring

The piston rings are gray cast iron, probably cast in cylinders and cut into rings. The composition is shown in Table V.

The manganese is high and the silicon is low for comparable American applications. High phosphorus gives fluidity to the casting. The nickel tends to offset the lack of silicon. Copper, also, is a graphitizer altho there is not enough present to be significant addition. The lack of chill in the casting indicates a practice to prevent this condition. The use of inocculants is possible.

There was no plating on the piston rings.

Hardness Tests:

Surface of compression rings	1	Rockwell "C"	29
	2		25
Surface of oil rings	1		24
	2		24-25
	3		29

The hardness values are within the limits for satisfactory wear resistance.

Microstructure:

There is a fine pearlite matrix with a large amount of steadite. The graphite is Type A, Size 5. This structure is desirable for wear resistance.

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Camshaft

The camshaft was forged from a carburizing grade of 1-3/4% nickel steel. The cams only were carburized; the sides of the cams, between the cams and the bearing surfaces were not hardened. The probable operations on the camshaft were; rough machine and rough grind cams, carburize and box cool, drill out center, turn between cams and rough grind, reheat, quench and temper, finish grind cams and bearings.

Hardness Test:

Shore scleroscope readings on cam face: Cams numbered from drive end.

1	82	7	81
2	80	8	80
3	82	9	79
4	81	10	80
5	82	11	81
6	80	12	80

Hardness Traverse on cross section of cam: Readings taken on center line of cam thru tip.

Distance from tip	Rockwell "C"
0.048"	64
0.105"	25
0.165"	20
0.260"	17
0.320"	17
Cam Surface	62-64

Hardness readings on bearing surfaces: Bearings numbered from drive end.

	Rockwell "C"	Rockwell "C" converted from Vickers, 1 Kg. Load
1	26	40.4, 39.1, 40.4
2	25.5	41.8, 41.8, 44.5
3	26.5	
4	26	
5	26	
End		22.8, 24.2, 18.8

Microstructure:

Case depth at tip - 0.100" (50% martensite)
Case depth at cam face - 0.055"
No case on inside diameter.
Case - Martensite and austenite (10 to 20%). No excess carbides. Structure resulting from very low temper.
Core - Acicular and blocky ferrite, transformation products and some martensite.

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Profilometer readings on cam face in micro inches. Cams numbered from drive end.

	Open Side	Close Side
1	30-35	28-32
1B	30-35	33-36
2	30-35	30-35
2B	40-45	40-45
3	30-35	32-35
3B	38-42	35-38
4	25-30	25-28
4B	28-33	28-30
5	34-38	37-40
5B	33-37	34-38
6	28-30	23-25
6B	25-30	21-24

Exhaust Valve

The exhaust valve is upset from chromium-silicon steel of composition shown in Table V. This is a standard automotive valve steel of nominal composition 5-10% Cr., 1-4% Si. It is resistant to scaling and can be hardoned to reduce wear on the stem. The molybdenum addition increases the elevated temperature strength and decreases susceptibility to temper brittleness. The valve is made in one piece with the stem drilled out to receive the adjusting screw.

Hardness Test:

Valve Head	Rockwell "C" 30
Solid Stem	Rockwell "C" 29-30
Hollow Stem	Rockwell "C" 30

Microstructure:

The carbides are spheroidized within the grains indicating a quench followed by high temper. Profilometer reading on stem: 23-25 micro inches.

Intake Valve

The intake valve is upset from Krupp steel of composition shown in Table V. It is made in one piece with the lower portion of the stem drilled out to receive the adjusting screw.

Hardness Test:

Valve head	Rockwell "C" 29
Solid Stem	Rockwell "C" 25-26
Hollow Stem	Rockwell "C" 27

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Microstructure:

Martensite highly tempered, with carbides spheroidized within the grain, indicates a quench and high draw.
Profilometer reading on stem: 19-20 micro inches

Valve Adjusting Screw

The valve adjusting screw was hot upset from nickel-chromium steel of composition shown in Table V. It was carburized only on the wearing surface of the flat head.

Hardness Test:

Rockwell "C" 57-59 on wearing surface of head.
Rockwell "C" 32 on stem.

Microstructure:

Case depth 0.035" - 0.040" on the wearing surface of the head. Case is martensite with a low temper. Reformed martensite present on the carburized surface of the screw with a tempered layer below. The body is low carbon martensite, acicular ferrite and some transformation products. The thread has no case and is not decarburized. The knurling under the head has no case but appears to be cold worked. The top of most of the knurls contains a lap where the metal is forced together. This operation was probably done after the screw had been given its final heat treatment.
Profilometer reading on wearing surface of head: In area of least build down, the finish is 6-8 and 7-11 micro inches.

Valve Adjusting Screw Lock Ring

The lock ring was machined from bar stock in excess of 2 inches in diameter. The material is a medium carbon chromium silicon steel having the composition shown in Table V.

Hardness Test:

Surface - Rockwell "C" 29-30.

Microstructure:

Tempered martensite resulting from quench and draw treatment.

The coating on the rings is an iron oxide, probably heat oxidation color.

Valve Springs

The inner and outer valve springs were coiled from 0.50% carbon, nickel chromium vanadium spring wire. The analysis is shown in Table V.

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Hardness Test:
Rockwell "C" 44 to 46.

Bend test - Satisfactory.

Load test:	Inner	Outer
Load @ 1-1/4"	26 lbs.	44 lbs.
	24.5	42.5
Solid Height	31/32	1
	31/32	1-1/16

Both springs are zinc coated with a thickness of zinc plate - 0.0005". The springs are shot peened with good coverage. Macro etching reveals a good surface condition, the wire being free from seams and die marks.

Valve Seat Insert

The intake and exhaust valve seats were machined from bar stock or tubing of the approximate composition FS 1045 with a quarter percent nickel content. The analysis is shown in Table V. The stock was probably normalized or only a fast cool from the finishing pass, with no other heat treatment.

Hardness Test:
Surface - Rockwell "C" 21 to 23, 20 to 21.
Rockwell "C" 20 to 23, 20

Microstructure
Fine pearlite with ferrite in the grain boundaries.

Valve Stem Guide

The valve stem guides were cast from plain cast iron of analysis shown in Table V. The manganese content is higher than generally used in automotive castings.

Hardness Test:
O.D. Rockwell "C" 22, 19
I.D. Rockwell "C" 22, 23
This hardness is desirable for wear.

Graphite - Type A - Size 5
Matrix - Pearlite and graphite. Usual amount of steadite. No free ferrite.
The fine structure indicates that an inocculant was used.
The guides have an iron oxide film on the surface.
Profilometer reading on I.D.:
Intake guide - 150-160 micro inches.
Exhaust guide - 170-180 micro inches.

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Oil Pump Gears

The oil pump gears were machined from medium carbon chromium silicon steel bars with the composition shown in Table V.

Hardness Test:

Tooth surface of six gears Rockwell "C" 33-36.

Microstructure:

Quenched and drawn structure of tempered martensite.

Oil Pump Drive Shaft with Integral Gear

The drive shaft was forged from Krupp steel and carburized and hardened all over. The analysis is shown in Table V.

Hardness Test:

Surface of tooth	Rockwell "C" 62
Center of tooth at pitch line	Rockwell "C" 43
Center of tooth at root line	Rockwell "C" 42
Core of gear	Rockwell "C" 39
Surface of shaft	Rockwell "C" 60-61

Microstructure:

Case depth at pitch line of tooth - 0.032"
Case depth at root line of tooth - 0.032"
Case - Martensite with excess carbides. Hardened by reheating. Low temper.
Core - Martensite and some transformation products.

Oil Pump Idler Shaft

The idler shaft was machined from a bar of carburizing grade molybdenum steel. The analysis is shown in Table V.

Hardness Test:

Surface - R"C" 66-67
Core - R"B" 92

Microstructure:

Case Depth - 0.028" - 0.030"
Case - Martensite.
Core - Blocky ferrite, low carbon martensite and transformation products.

Water Pump Shaft

The water pump shaft was machined from bar stock greater than 2-1/4" round, which is the diameter of the flange. The impeller is riveted to this flange on the end of the shaft. The steel used is a carburizing grade of nickel chromium composition as shown in Table V.

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Hardness Test: - Surface of shaft Rockwell "C" 63.

Microstructure:

Case depth 0.040".
Case - Martensite with excess carbides and possibly low temper.
Core - Martensite, transformation products and acicular ferrite.

Fuel Injection Tube - Pump to Cylinder Nozzle

The tubes were made of thick walled, cold drawn seamless steel tubing. The composition corresponds to F.S. 1020.

Hardness Test:

Tube Surface - Rockwell "B" 63-64

Microstructure:

The structure is ferrite with scattered areas of spheroidized pearlite which resulted from an annealing treatment. The hole is decarburized 0.002 to 0.003" and some scale is present. The diameter of the hole is not perfectly symmetrical, measuring 0.072 to 0.080". On the outside surface of the tube the decarburization is nil. The outside diameter of the tube is 0.280".

Air Starter Injection Tube

The tubes were made of seamless steel tubing. The composition corresponds to F. S. 1010. The tubes were plated with approximately 0.0004" of zinc.

Microstructure:

There is a small amount of pearlite scattered in a ferrite matrix with cementite in some of the grain boundaries. This is a typical low carbon structure.

The outside diameter of the tubing is 0.313". The inside diameter is 0.220" with a wall thickness of 0.042".

Spray Nozzle and Spring from Bosch Fuel Injection System

The coating on the surface is an iron oxide, probably heat treat scale.

Air Starter Nozzle Assembly

The steel cap is copper plated - Cu 0.0006". The other parts are not coated.

Strap - Generator Mounting Bracket

The steel strap is plated with approximately 0.0004" zinc.

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Flywheel Ring Gear

The gear was used as machined with no subsequent heat treatment. The edges of the teeth are battered from the action of the starter pinion. The gear is not significantly file resistant.

Cylinder Head Cover

The cylinder head cover on each bank of the engine is cast iron.

Oil Manifold Bearing Flange - Accessory End of Crankshaft

The bearing seat of this steel part was carburized 1/32" and hardened. A bronze bushing slips over the hardened end of the crankshaft. The bushing can turn on the crankshaft or against the hardened flange of this part.

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TABLE V

ENGINE PARTS - STEEL

Part Name	C	Mn	P	S	Si	Cr	Ni	Mo	Case Depth	Hardness O.D.	Hardness Core	Ht.
Crankshaft	.14	.47	.016	.014	.25	1.68	3.57	.11		375	375	Q & T
Conn. Rod, Master	.18	.35	.021	.024	.20	1.80	3.70	.28		340		Q & T
Conn. Rod, Link	.18	.43	.010	.012	.41	1.54	3.97	.11		351		Q & T
Conn. Rod, Brg. Cap	.21	.40	.013	.016	.36	1.69	3.98	.16		36-37		Q & T
Piston Pin	.15	.40	.016	.016	.25	.76	2.71	.04	.040"	60	32	Carb.
Pin - Link Rod	.11	.30	.021	.038	.25	.77	2.88	.07	.048"	63	32	Carb.
Screw - Rod Pin Retainer	.37	.40	.013	.018	.96	1.70	.12	None		24		Q & T
Stud - Cyl. Head	.19	.49	.017	.012	.40	1.62	4.11	.14		33-35		Q & T
Stud - Main Brg. Cap	.19	.44	.027	.029	.24	1.66	3.85	.21		33-35		Q & T
Stud - Conn. Rod - Brg. Cap	.24	.33	.017	.024	.28	1.53	3.88	.16		33-35		Q & T
Thru Rod	.22	.31	.020	.020	.27	1.68	4.19	.31		30-33		Q & T
Cylinder - Liner	.38	.38	.017	.018	.22	1.45	.15	.21	Cu Al .20 .75 .015	63	31	Nitride
Camshaft	.14	.40	.018	.015	.19	.18	1.69	.04	.110/.065	64	17	Carb.
Exhaust Valve	.39	.37	.020	.018	2.17	10.92	.38	.95		30		Q & T
Intake Valve	.24	.51	.028	.026	.25	1.17	3.58	.11		29		Q & T
Ex Valve Adj. Screw.	.22	.40	.021	.016	.35	.79	2.67	.04	.037"	59-61	28	Carb.
In. Valve Adj. Screw.	.16	.40	.017	.020	.34	.79	2.69	.04	.040	57-59	32	Carb.
Ex. Valve Adj. Screw. - Lock Ring	.39	.47			1.20	1.61	.07	None		29-30		Q & D
In. Valve Adj. Screw - Lock Ring	.35	.47			1.20	1.34 V .98 .16	.07	None		27-29		Q & D
Ex. Valve Spring Outer	.50	.36	.016	.015	.29	1.01 .17	.33	.03		44-46		Q & D
Ex. Valve Spring Inner	.50	.34	.015	.018	.30	1.07 .16	.34	.02		44-46		Q & D
In. Valve Spring Outer	.46	.43	.015	.016	.21	.87 .16	.39	.04		44		Q & D
In. Valve Spring Inner	.48	.43	.015	.016	.25	.87 .16	.35	.03		44		Q & D
Valve Seat Insert	.46	.57	.029	.026	.16	.06	.23	None		20		Norm.
Ex. Valve Stem Guide	3.17	1.32	.118	.102	2.39	.21	.28	None		22		
In. Valve Stem Guide	3.29	1.50	.104	.086	2.33	.20	.12	None		23		
Oil Pump Gear	.38	.63	.024	.022	1.32	1.46	.15	.04		35		Q & T
Oil Pump Drive Shaft	.19	.37	.022	.018	.22	1.43	3.69	.25	.032"	62	39	Carb.
Oil Pump Idler Shaft	.20	.59	.037	.037	.12	.11	.13	.23	.030'	66-67	92 R"B"	Carb.
Water Pump Shaft	.12	.32	.023	.029	.24	.82	2.87	.11	.040	63		Carb.

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ACCESSORY DRIVE PARTS

Crankshaft Gear

The crankshaft gear is an upset forging made of Krupp steel. The analysis is shown in Table VI. The gear was carburized and hardened.

Hardness Test:

Surface of tooth	Rockwell "C" 62
Center of tooth at pitch line	Rockwell "C" 43
Center of tooth at root	Rockwell "C" 39
Core of gear	Rockwell "C" 27

Microstructure:

Case depth at pitch line 0.050"
Case depth at root 0.050. Probably hardened beyond the 0.50% carbon level penetration.
Case - Martensite, possible low temper, excess carbides in form of spheroids.
Core - Martensite, some transformation products, and ferrite.

Crankshaft Gear Thrust Plate

The thrust plate was made of through hardening spring steel of the approximate composition FS1070. The analysis is shown in Table VI.

Hardness Test:

On ground surface, Rockwell "C" 52-53.

Microstructures:

Quenched and tempered.

Pinion - Main Accessory Drive - Lower (From crankshaft gear)

The pinion is an upset forging made of nickel chromium steel, carburized and hardened. The analysis is shown in Table VI.

Hardness Test:

Surface of tooth	Rockwell "C" 62
Center of tooth at pitch line	Rockwell "C" 40
Center of tooth at root	Rockwell "C" 37
Core of pinion	Rockwell "C" 37

Microstructure:

Case depth at pitch line 0.030"
Case depth at root 0.027"
Case - Martensite, possibly low temper.
Core - Martensite with some transformation products.

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Shaft - Main Accessory Drive
(For air distributor, fuel injector and camshaft)

The shaft was made of nickel chromium steel, carburized and hardened. The analysis is shown in Table VI.

Hardness Test:

Surface of tooth	Rockwell "C" 62
Center of tooth at pitch line	Rockwell "C" 27
Center of tooth at root	Rockwell "C" 25
Core of pinion	Rockwell "C" 24
Bearing surface of shaft	Rockwell "C" 60

Microstructure:

Case depth at pitch line 0.028"
Case depth at root 0.028"
Case - Martensite with possible low temper, following hardening by reheating.
Core - Martensite, about 50% ferrite and a slight trace of transformation products.

Injector Pump Drive Pinion

The injector pump drive pinion is an upset forging made of nickel chromium steel, carburized and hardened. The analysis is shown in Table VI.

Hardness Test:

Surface of tooth	Rockwell "C" 62
Core of pinion	Rockwell "C" 38

Microstructure:

Case depth at pitch line 0.050"
Case depth at root 0.050"
Case - Martensite with grain boundary network of carbides. Possibly low temper.
Core - Low carbon martensite, mostly blocky ferrite with small amount of acicular ferrite and trace of transformation products.
The structure indicates a reheat after carburizing. The case extends all over the outside surface of the pinion. The bore and internal splines do not appear to be carburized. In fact, the splines are slightly decarburized.

Lower Camshaft Drive Gear with Internal Splined Sleeve

The drive gear is an upset forging made of nickel chromium steel, carburized and hardened. The analysis is shown in Table VI.

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Hardness Test:

Surface of tooth	Rockwell "C" 61
Center of tooth at pitch line	Rockwell "C" 41
Center of tooth at root	Rockwell "C" 39
Core of gear	Rockwell "C" 32
Bearing surface of sleeve	Rockwell "C" 60-61

Microstructure:

Case depth at pitch line 0.035"
Case depth at root 0.028" - 0.030"
Case - Martensite with only a trace of excess carbides.
Core - Low carbon martensite, acicular and blocky ferrite and some transformation products.
The pinion was hardened by reheating after carburizing.

Camshaft Drive Pinion

The camshaft drive pinion was made of nickel chromium steel, carburized and hardened. The analysis is shown in Table VI.

Hardness Test:

Surface of tooth	Rockwell "C" 61
Center of tooth at pitch line	Rockwell "C" 42
Center of tooth at root	Rockwell "C" 38
Core of pinion	Rockwell "C" 35
Bearing surface of shaft	Rockwell "C" 61

Microstructure:

Case depth at pitch line 0.030"
Case depth at root line 0.030"
Case - Martensite, excess carbides and some austenite with low temper. Hardened from reheat.
Core - Martensite and some transformation products.

Camshaft Drive Pinion Thrust Washer

The thrust washer was made of through hardening steel of the approximate composition FS 1090. The analysis is shown in Table VI.

Hardness Test:

On ground surface Rockwell "C" 58-59.

Microstructure:

Martensite with small spheroids of carbide dispersed through the matrix. There was possibly a low temper.

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Generator Drive Shaft

The drive shaft was forged from Krupp steel, machined all over, carburized and hardened. The analysis is shown in Table VI.

Hardness Tests:

Surface of tooth	Rockwell "C" 62
Pitch line of tooth	Rockwell "C" 47
Root of tooth	Rockwell "C" 44
Core of tooth	Rockwell "C" 38
Bearing surface of shaft	Rockwell "C" 62
Surface of washers used	Rockwell "C" 55-57

Microstructure:

Case depth at pitch line of tooth 0.032"
Case depth at root of tooth 0.032"
Case - Martensite, a few excess carbides and some austenite. Possibly low temper.
Core - Low carbon martensite and some transformation products.

Generator Drive Gear

The drive gear was machined all over from nickel chromium steel, carburized and hardened. The analysis is shown in Table VI.

Hardness Tests:

Surface of tooth	Rockwell "C" 62
Pitch line of tooth	Rockwell "C" 40
Root of tooth	Rockwell "C" 32
Core of tooth	Rockwell "C" 29

Microstructure:

Case depth at pitch line of tooth 0.038"
Case depth at root of tooth 0.038"
Case - Martensite, excess carbides, possibly low temper.
Core - Martensite and about 10-20% ferrite.
The part was probably reheated for hardening after carburizing.

Generator Coupling Drive Shaft

The drive shaft was made from Krupp steel, probably a forging, machined all over, carburized and hardened. The analysis is shown in Table VI.

Hardness Tests:

Surface of tooth	Rockwell "C" 59
Pitch line of tooth	Rockwell "C" 45
Root of tooth	Rockwell "C" 44
Core of tooth	Rockwell "C" 42
Bearing surface of shaft	Rockwell "C" 62

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Microstructure:

Case depth at pitch line of tooth
Case depth at root of tooth
Case - Martensite, and small amount of austenite. Possibly low temper.
Core - Martensite with a small amount of transformation products. The part appears to have been direct quenched from the carburizing operation.

Camshaft Drive Gear

The drive gear was forged by upsetting so that the flow lines are lengthwise of the teeth. A carburizing grade of nickel chromium steel was used. The analysis is shown in Table VI. The gear was machined all over, carburized and hardened.

Hardness Tests:

Surface of tooth of straight tooth gear	Rockwell "C" 61-61
Core of tooth of straight tooth gear	Rockwell "C" 29-30
Surface of tooth of bevel tooth gear	Rockwell "C" 62-64
Core of tooth of bevel tooth gear	Rockwell "C" 28-30

Microstructure:

Case depth at pitch line of tooth
Case depth at root of tooth
Case - Martensite with a large amount of spheroids of carbide.
Core - Martensite, blocky ferrite and a small amount of transformation products.

Camshaft Timing Adjusting Sleeve and Screw

The parts were machined of through hardening steel.

Hardness Tests:

Hub of sleeve	Rockwell "C" 39-40
Head of screw	Rockwell "C" 29-30

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TABLE VI

ACCESSORY DRIVE PARTS

Part Name	C	Mn	P	S	Si	Cr	Ni	Mo	Hardness Case Depth	Hardness Case O.D.	Core	Ht.
Crankshaft Gear	.15	.41	.025	.022	.29	1.46	3.21	.07	.050 '	62	27	Carb.
Crankshaft Gear Thrust Plate	.66	.93	.035	.031	.23	.05	.12	None		52		Q & T
Pinion from CS Gear	.18	.40	.019	.019	.26	.91	3.24	.12	.030	62	37	Carb.
Shaft - Acc. Drive, Upper	.15	.43	.021	.015	.25	.92	2.49	.05	.028 "	62	24	Carb.
Pinion - Inj. Pump	.13	.45	.028	.010	.39	.91	2.82	.07	.050	62	38	Carb.
Dr. Gear - Lower Cam	.14	.44	.020	.021	.25	.71	2.64	.05	.035	61	32	Carb.
Cam - Drive Pinion	.14	.38	.031	.031	.27	1.08	2.99	.10	.030	61	35	Carb.
Drive Shaft - Gen.	.17	.46	.018	.018	.31	1.60	4.16	.32	.032	62	38	Carb.
Gear - Gen. Drive	-	.46	-	-	.20	.94	2.42	.05	.038	62	29	Carb.
Shaft - Gen. Coupling Dr.	.21	.40	.028	.030	.23	1.71	3.82	.32	.032	62-59	42	Carb.
Gear - Camshaft Dr.	.12	.46	.017	.018	.28	.85	3.10	.03	.040	62-64	28-30	Carb.

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Lower Gear - Oil - Water - Fuel Pump Drive Main Shaft

The gear was forged from a carburizing grade of nickel chromium steel, machined all over, carburized and hardened.

Hardness Tests:

Surface of tooth	Rockwell "C" 62
Surface of bearing on sleeve	Rockwell "C" 60-61

Microstructure:

Case depth at pitch line of tooth 0.024"
Case depth at root of tooth 0.024"
Case - Martensite with few scattered excess carbides.
Core - Low carbon martensite, transformation products and acicular and some blocky ferrite.
The part was probably reheated for hardening after carburizing with a low temper following.

Fuel Pump Drive Idler Gear

The gear was forged from a carburizing grade of nickel chromium steel, machined all over, carburized and hardened.

Hardness Tests"

Surface of tooth	Rockwell "C" 60
Ground surface of stem	Rockwell "C" 35-38

Microstructure:

Case depth at pitch line of tooth 0.023"
Case depth at root of tooth 0.023"
Case - Martensite with large carbides in the grain boundaries on the very surface, light carbide network just below the surface.
Core - Low carbon martensite with some transformation products.
The part was probably reheated for hardening after carburizing with a low temper following.
The part was probably reheated for hardening after carburizing with a lower temper following.

Oil Pump Drive Idler Gear

The gear was machined from a carburizing grade of nickel chromium steel, machined all over, carburized and hardened on the teeth.

Hardness Tests:

Surface of tooth	Rockwell "C" 62
Hub	Rockwell "C" 35

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Microstructure:

Case depth at pitch line of tooth 0.028"
Case depth at root of tooth 0.028"
Case - martensite, a few globular carbides on surface with a fine carbide network just below the surface.
Core - low carbon martensite, transformation products and acicular ferrite.
The part was probably reheated for hardening after carburizing with a low temper following.

Oil-Water - Fuel Pump Drive Bevel Gear to Crankshaft

The gear was forged from a carburizing grade of nickel chromium steel, machined all over, carburized and hardened.

Hardness Tests:

Surface of tooth	Rockwell "C" 58-60
Surface of bearing on shaft	Rockwell "C" 62-63
Center portion of shaft	Rockwell "C" 25-33
Top of splines	Rockwell "C" 33

Microstructure:

Case depth at pitch line of tooth 0.030"
Case depth at root of tooth 0.030"
Case - martensite with very light carbide network in grain boundaries.
Core - low carbon martensite and some transformation products.
The part was probably reheated for hardening after carburizing, with a low temper following.

Tachometer Drive Gear - Bevel, Driven

The gear was machined from a carburizing grade of nickel chromium steel, carburized and hardened.

Hardness Tests:

Surface of tooth	File hard to a R "C" 59 File
Pilot End	Rockwell "C" 37
Spiral Spline	Rockwell "C" 51
End of stem	Rockwell "C" 49

Microstructure:

Case depth at pitch line of tooth 0.022"
Case depth at root of tooth 0.022"
Case - martensite with a grain boundary carbide network.
Core - low carbon martensite with some transformation products.
The part was probably reheated for hardening after carburizing with a low temper following.

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Tachometer Drive Pinion - Bevel, Drive

The pinion was machined from a carburizing grade of nickel chromium steel, carburized and hardened.

Hardness Tests:

Surface of tooth	Rockwell "C" 60
Bearing surface of stem	Rockwell "C" 60-62

Microstructure:

Case depth at pitch line of tooth 0.022"
Case depth at root of tooth 0.022"
Case - martensite with a few scattered carbides.
Core - low carbon martensite, transformation products and acicular ferrite.
The part was probably reheated for hardening after carburizing, with a low temper following.

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TRANSMISSION

The transmission gears and shafts were made of Krupp steel. The analysis of the individual parts is shown in Table VII. The gears and reverse idler shafts were carburized and hardened. The transmission mainshaft and countershaft were quenched and drawn, only. The carbon content of these two shafts remained the same and the nickel and molybdenum was increased over the carburized parts to provide increased hardenability to through-harden the 3-1/8" section. All of the carburized parts have a hypereutectoid case with excess carbides to a depth of 0.017" to 0.033". There are massive carbides at the surface with a continuous network beneath, fading into discontinuous carbides. This condition is conducive to brittleness and spalling on the ends of clash gears as was shown in this transmission. It is likely all of the transmission gears were reheated for hardening after carburizing. The gears with internal splines in the hub appear to have been quenched on a plug fixture as the splines are not file hard. The web of each gear is file hard.

In measuring case depth of the gears difficulty was experienced because of the similarity of case and core structures under the microscope due to the high hardenability of the Krupp steel. To check the depth of case as measured on the cross section of a hardened tooth, a Vickers hardness traverse of the case was made and the location of the Rockwell "C" 45-50 hardness position noted. As a further check, a gear tooth was annealed and the depth of penetration to the 0.4% carbon point estimated.

The residue, scraped from the bottom of the transmission case, after draining the lubricant consists of iron (96%) oil and carbon. There is no aluminum and no silicon.

This material came from the flakes and ground up chips from the gear teeth mixed with oil, and was not formed from particles from the transmission case or dirt from the outside.

Transmission Mainshaft

The mainshaft was machined from a bar and after heat treatment was shot blasted and then the splines were finish ground.

Hardness Test:

Surface of shaft	B.H.N. 387
1/2 Radius	B.H.N. 387
Surface of spline	B.H.N. 375,-R"C" 42

There was a Russian brinell impression near the center shoulder on top of one of the 10 splines. The preparation was a rough grind and the impression was close to the edge of the spline and metal was forced over the edge.

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Microstructure:

Low carbon martensite with a small amount of transformation products present.

Transmission Countershaft

The countershaft was machined from a bar and after heat treatment was shot blasted and then the splines were finish ground.

Hardness Test:

Surface of shaft	B.H.N. 387
1/2 Radius	B.H.N. 387
Center of shaft	B.H.N. 378
Surface of spline	B.H.N. 387, R"C" 41

There was a Russian brinell impression near the outer shoulder on top of one of the 10 splines.

Microstructure:

Tempered low carbon martensite throughout the cross section.

Reverse Idler Shaft

The reverse idler shaft was machined from bar stock and after carburizing and hardening was finish ground. The end of the shaft for a distance of 3-1/4" outside the bearing surface was left as rough turned. The balance of the shaft was ground.

Hardness Test:

Surface	Rockwell "C" 61
Core 1/2 Radius	B.H.N. 321
Center	B.H.N. 302

Microstructure:

Case depth - 0.078"

Case - Martensite with spheroids of excess carbides. Carbide also in grain boundaries.

Core - Low carbon martensite and transformation products.

Reverse Idler Gear

The reverse idler was upset to form two gears in a cluster so that the flow lines were bent to form the tooth section of each gear. It was machined all over, carburized and hardened. The gear was shot blasted and the finish grind operations performed. The finish ground bore of the gear, which acts as a bearing seat, was file hard. The chamfered edge of the 15 tooth gear is battered and worn and chipped. The base of the tooth has a heavy groove worn on a taper starting at the edge of the tooth. The 16 tooth gear has grooves worn the full length of the tooth at the base. Photograph 0702.5.6 a

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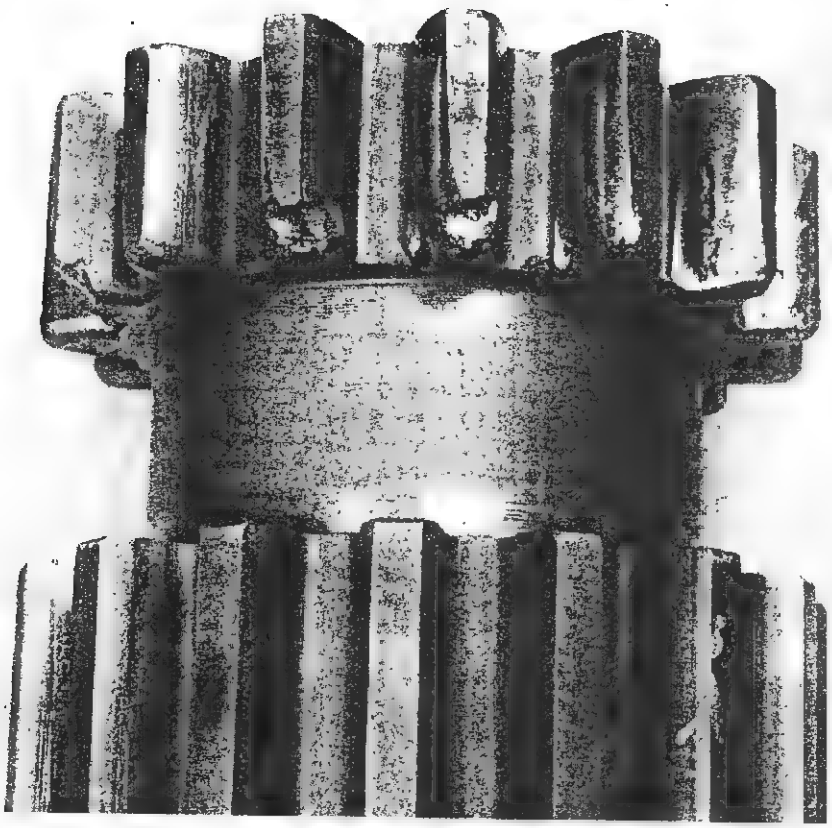

0702.5.6 a - REVERSE IDLER GEAR CLUSTER

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Hardness Test:	15 Tooth Gear	16 Tooth Gear
Surface of tooth	Rockwell "C" 61-62	61
Center of tooth at pitch line	42	41
Center of tooth at root	41	40
Core of gear	39	38

Microstructure:

Case depth at pitch line 0.075"
Case depth at root 0.062"
Case - Martensite with excessive carbides to a depth of 0.033". Possibly low temper.
Core - Low carbon martensite, some acicular ferrite and transformation products.

2nd Speed Gear

The second speed gear was forged, machined, carburized all over and hardened except for the bore. The gear was then shot blasted and the top of the splines on the inside of the hub rough ground. The chamfered ends of the teeth were battered. Grooves were worn on both sides of the teeth at the bottom. Photograph 0702.3.2

Hardness Test:	
Surface of tooth	Rockwell "C" 61
Center of tooth at pitch line	Rockwell "C" 39
Center of tooth at root	Rockwell "C" 37
Core of gear	Rockwell "C" 37

A Russian brinell impression had been made on the end of the splined hub on the machined surface.

Microstructure:

Case depth at pitch line 0.065"
Case depth at root 0.060"
Case - Martensite with excess carbides to a depth of 0.027". Possibly low temper.
Core - Martensite and a small amount of transformation products.

1st Speed Gear

The first speed gear was forged, machined, carburized all over and hardened except for the bore. The gear was then shot blasted and the top of the splines on the inside of the hub rough ground. The ends of the hub were faced. Both engaging ends of the teeth were battered and chipped. There appeared to be inadequate chamfer. The teeth were heavily worn on opposite ends on both sides. Photograph 0702.3.1 a

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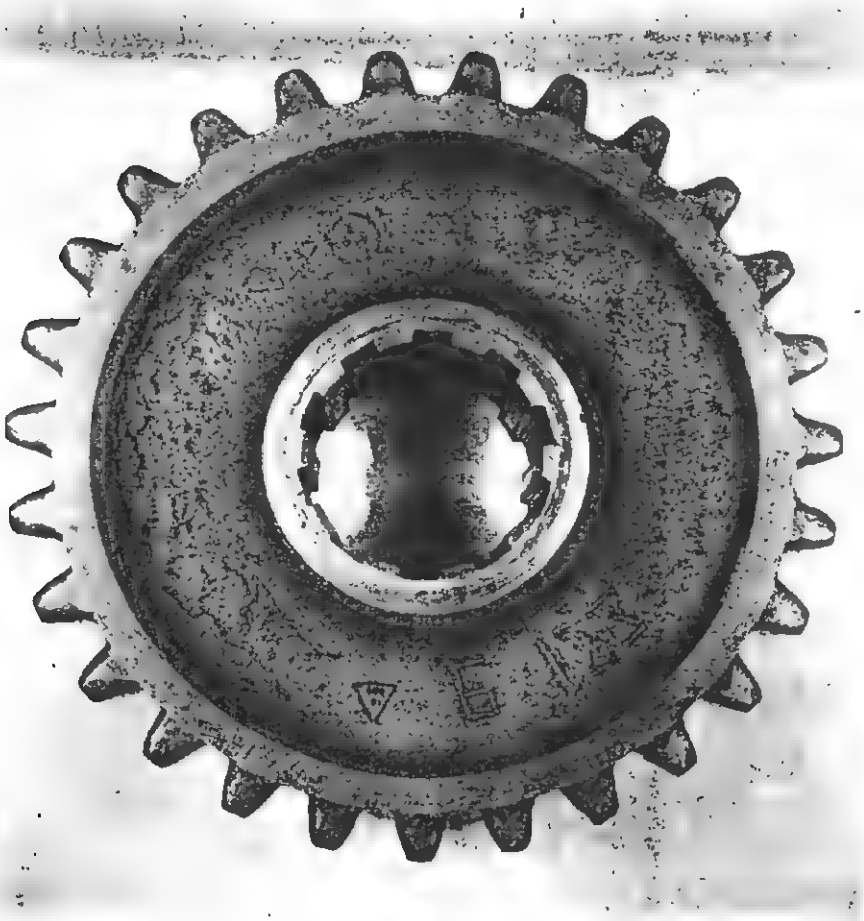

0702.3.2 - SECOND SPEED DRIVEN GEAR

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0702.3.1 a - FIRST SPEED DRIVEN GEAR

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Hardness Test:

Surface of tooth	Rockwell "C" 61
Center of tooth at pitch line	Rockwell "C" 37-39
Center of tooth at root	Rockwell "C" 37
Core of gear	Rockwell "C" 36.5

A Russian brinell impression had been made on the end of the splined hub on the machined surface.

Microstructure:

Case depth at pitch line 0.055"
Case depth at root 0.055"
Case - Martensite with excess carbides to a depth of 0.021". Possibly low temper.
Core - Low carbon martensite. Acicular ferrite and transformation products.

3rd and 4th Speed Sliding Gear (Photograph 0702.3.3)

The 3rd and 4th speed sliding gear was upset to form two gears in a cluster so that the flow lines were bent to form the tooth section of each gear.

It was machined all over, carburized and hardened. The gear was shot blasted and the top of the splines on the inside of the hub rough ground. The engaging ends of both gears of this cluster are chipped and battered. The 14 tooth gear has evidence of pitting at the base of the teeth on one side and both sides of the teeth are burnished below the tool marks. The 21 tooth gear has considerable wear on one side of the tooth face.

Hardness Test:	14 Tooth Gear	21 Tooth Gear
Surface of tooth	62	61
Center of tooth at pitch line	40-41	41
Center of tooth at root	40-41	39
Core of gear	37-39	40

A Russian hardness test was made on the hub on the 21 tooth gear side. There was a slight grind and a near miss of the brinell impression.

Microstructure:

Case depth at pitch line 0.058"
Case depth at root 0.055"
Case - Martensite with excess carbides to a depth of 0.028". Possibly low temper.
Core - Low carbon martensite and transformation products.

1st and 2nd Speed Countershaft Gear

The 1st and 2nd speed countershaft gear was upset to form two gears in a cluster so that the flow lines were bent to form the tooth section of

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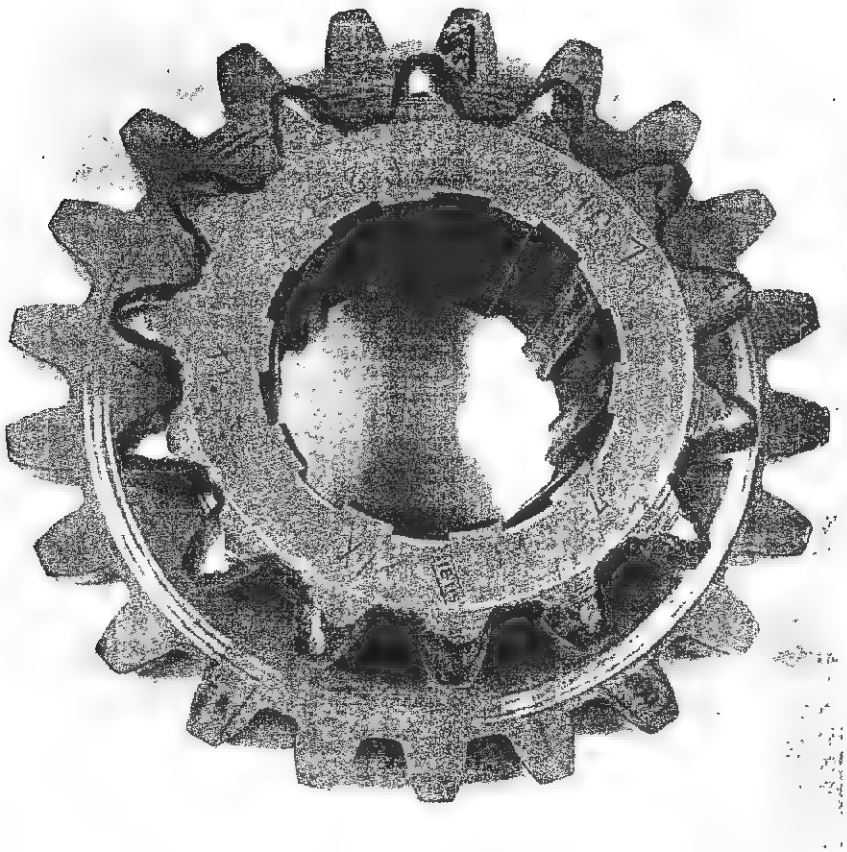

0702.3.3 - THIRD AND FOURTH SPEED DRIVEN GEAR CLUSTER

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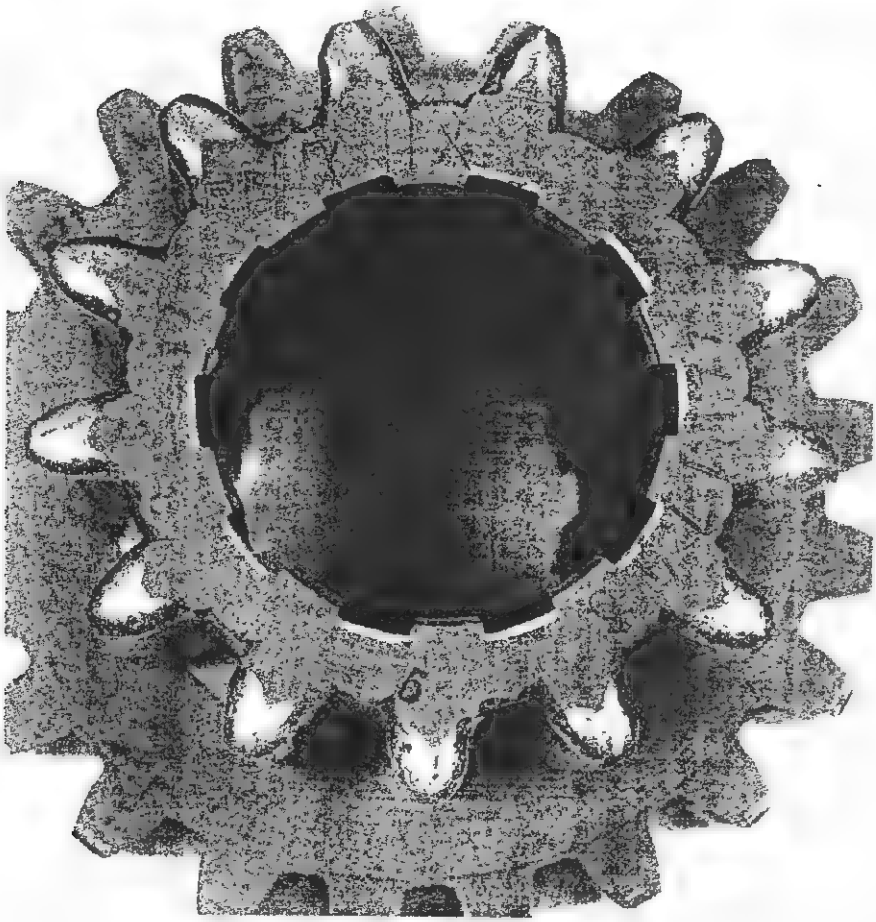

0702.5.2 - FIRST, SECOND, AND REVERSE IDLER DRIVE GEAR CLUSTER

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each gear. It was machined all over, carburized and hardened. The gear was shot blasted and the top of the splines on the inside of the hub rough ground. The engaging ends of both gears of this cluster are chipped and battered. Photograph 0702.5.2. The 13 tooth gear has one side of the teeth pitted and worn by both mating gears. The other side of the teeth is burnished below the tool marks. The 21 tooth gear has one side of the teeth pitted and worn; the other side is burnished below the tool marks.

Hardness Tests:	13 Tooth Gear	21 Tooth Gear
Surface of tooth	Rockwell "C" 61.5	61
Center of tooth at pitch line	39	37
Center of tooth at root	36	35
Core of gear	29	30

A Russian brinell impression had been made on the splined end of the hub on the 21 tooth side.

Microstructure:

Case depth at pitch line 0.072"
Case depth at root 0.065"
Case - Martensite with excess carbides to a depth of 0.028". Possibly low temper.
Core - Low carbon martensite, transformation products and some acicular ferrite.

4th Speed Countershaft Gear

The fourth speed gear was forged, machined, carburized and hardened, except for the bore. The gear was then shot blasted and the grinding operations performed. The chamfered ends of the teeth were battered. A flat was worn at the pitch line of the drive side of the teeth.

Hardness Test:	
Surface of tooth	Rockwell "C" 62
Center of tooth at pitch line	Rockwell "C" 42
Center of tooth at root	Rockwell "C" 42
Core of gear	Rockwell "C" 39-42

Microstructure:

Case depth at pitch line 0.048"
Case depth at root 0.045"
Case - Martensite with excess carbides to a depth of 0.017". Possibly low temper.
Core - Martensite with transformation products.

3rd Speed Countershaft Gear

The third speed gear was forged, machined, carburized all over and hardened except for the bore. The gear was then shot blasted and the top of

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the splines on the inside of the hub rough ground. The chamfered ends of the teeth were battered and worn. The tooth face on both sides was burnished below the tool marks.

Hardness Test:

Surface of tooth	Rockwell "C" 60 to 61
Center of tooth at pitch line	Rockwell "C" 36
Center of tooth at root	Rockwell "C" 34
Core of gear	Rockwell "C" 34

A Russian brinell impression had been made on the splined end of the hub.

Microstructure:

Case depth at pitch line 0.065"
Case depth at root 0.065"
Case - Martensite with excess carbides to a depth of 0.027". Possibly low temper.
Core - Martensite with transformation products.

Transmission Drive Gear

The spiral bevel ring gear is bolted to the 4th speed countershaft gear. It was forged, machined, carburized and hardened all over. The gear was then shot blasted and the finish grind operations on the bore and back of the gear performed. The teeth show even wear with the bearing full tooth to the toe on the drive side.

Hardness Test:

Surface of tooth	Rockwell "C" 60
Center of tooth at pitch line	Rockwell "C" 45
Center of tooth at root	Rockwell "C" 45
Core of gear	Rockwell "C" 37

The ground surfaces of the bore and back of the gear are file hard.

Microstructure:

Case depth at pitch line 0.045"
Case depth at root 0.042"
Case - Martensite with excess carbides to a depth of 0.024". Possibly low temper.
Core - Martensite with transformation products. No free ferrite visible.

Transmission Drive Pinion

The spiral bevel stem pinion was upset to form the head, machined, carburized and hardened. The finish grinding operations were performed after hardening. The machined finish on the teeth has the appearance of roughness. The bearing on the teeth is toward the toe on the drive and reverse sides.

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Hardness Test:

Surface of tooth	Rockwell "C" 62
Center of tooth at pitch line	Rockwell "C" 39
Center of tooth at root	Rockwell "C" 38
Core of pinion	Rockwell "C" 38
Bearing seat of shaft, surface,	Brinell - 277
Shaft at spline, surface	Brinell - 277

Surface hardness survey of shaft - 294 - 279
(From pinion to spline end - converted from R "C")
The pinion, only, is case hardened; the bearing seat, remainder of the stem and the splines are not file hard.

A Russian brinell impression had been made on the end of a tooth on a rough ground spot.

Microstructure:

Case depth at pitch line 0.055"
Case depth at root 0.055"
Case - Martensite with excess carbides to a depth of 0.022". Possibly low temper.
Core - Martensite with some transformation products. Carbon somewhat spheroidized deep in core.

Starting Motor Pinion

Hardness Test:

Top of pinion teeth	Rockwell "C" 39-40
Bearing seat of shaft	Rockwell "C" 35-37
Spiral spline	Rockwell "B" 92

The spiral splines on the driven end of the shaft have been tempered at a high temperature. This portion of the pinion shaft mates with the bronze drive hub in the clutch assembly.

A Rockwell impression on top of the pinion teeth was made by Russian inspectors. This is the only instance of Rockwell hardness testing noted on this vehicle.

Gear Shift Rails

The gear shift rails were machined from through hardened steel bars of medium carbon, Cr., Ni., Si. composition. The analysis is shown in Table VII. The bars were cut to length and centered before heat treatment. Possibly a certain amount of rough machining was also done before heat treatment, but the whole surface of the rail except the centered ends had been machined or ground after heat treating. There was no special hardening at the ramps and some wear had resulted at the shoulders.

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Hardness Tests:

	1st and 2nd	3rd and 4th	Reverse
Surface at Ramp	R"C" 27 to 29	R"C" 28 to 30 29 to 31 29 to 32	R"C" 28 to 29
Surface between ramps	B.H.N. 286	R"C" 32	B.H.N. 277
Core of rail	B.H.N. 269		

Microstructure:
Tempered martensite resulting from high draw.

Gear Shift Forks

The gear shift forks were forged from a medium carbon, chromium, nickel, silicon steel and through hardened. They were machined after heat treatment. The analysis is shown in Table VII.

There was no special hardening on the tips or wearing surfaces of the forks.

Hardness Tests:

Tip or fork surface	R"C" 27 to 29	R"C" 32	R"C" 28 to 29 (I.D.)
Core of fork	R"C" 28	R"C" 28.5	R"C" 31 to 32

Microstructure:
Tempered martensite resulting from high draw.

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TABLE VII

TRANSMISSION PARTS

Part Name	C	Mn	P	S	Si	Cr	Ni	Mo	Hardness Case Depth	Hardness Core		Ht.
Mainshaft	.16	.39	.022	.027	.21	1.70	4.28	.34	-	387	387	Q & D
Countershaft	.15	.40	.021	.026	.21	1.75	4.50	.31	-	387	378	Q & D
R.I. Shaft	.14	.35	.021	.025	.20	1.71	3.56	.04	.078	61	321	Carb.
Reverse Idler	.18	.44	.022	.024	.19	1.69	3.61	.08	.075	61	42	Carb.
2nd Speed	.14	.43	.019	.025	.30	1.65	3.56	.11	.070	61	37	Carb.
1st Speed	.13	.38	.014	.022	.28	1.61	3.72	.13	.055	61	37	Carb.
3 and 4 Sliding Gear	.15	.39	.023	.013	.17	1.77	3.60	.11	.058	61	40	Carb.
1 and 2 C. S. Gear	.16	.39	.027	.029	.15	1.55	3.67	.12	.072	61	37	Carb.
4th C. S. Gear	.17	.48	.026	.028	.18	1.57	3.85	.12	.048	62	39-40	Carb.
3rd C. S. Gear	.19	.43	.021	.021	.19	1.65	3.40	.11	.065	60-61	34	Carb.
Ring Gear	.18	.34	.020	.021	.22	1.33	4.28	.07	.045	60	45	Carb.
Drive Pinion	.16	.36	.025	.020	.25	1.59	4.22	.09	.055	62	38	Carb.
G. S. Rail Reverse	.36	.39	.022	.032	1.05	1.75	.29	.02	-	28-29	277	Q & D
G. S. 1 and 2	.35	.39	.024	.025	1.02	1.64	.25	.13	-	27-29	269	Q & D
G. S. 3 and 4	.34	.40	.025	.029	1.04	1.70	.41	.05	-	28-32		Q & D
G. S. Fork Reverse	.36	.48	.015	.012	1.10	1.62	.30	.02	-	28-29	31-32	Q & D
G. S. Fork 1 and 2	.36	.40	.019	.023	1.39	1.46	.24	.05	-	27-29	277	Q & D
G. S. Fork 3 and 4	.42	.49	.023	.020	1.34	1.60	.31	.07	-	32	285	Q & D

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STEERING PARTS

Brake Lining

The brake lining was made of cast iron, cast in segments, curved to fit the brake drum.

Chemical Analysis:

T.C.	3.29%	Si	2.49%
C.C.	0.37	Cr	0.16
P	0.122	Ni	0.33
S	0.098	Mo	None

The manganese is high for comparable American practice. The chromium and nickel content shown indicate additions.

Physical Tests:

A tensile test piece was machined from the segment and gave the following results:

Ultimate tensile strength	26,900 psi
Brinell Hardness (3000 Kg.)	196

Microstructure:

Graphite - Type A (some C), Size 4.
Structure - Coarse pearlite, graphite and small amount of ferrite. No porosity was evident.

Pins - Steering Clutch Spring

The pins were machined from 3/4" round, cold drawn bars with no hardening operation. The approximate grade is FS 1030.

Chemical Analysis:

C	0.30%	Si	0.23%
Mn	0.59	Cr	0.18
P	0.018	Ni	0.25
S	0.023	Mo	None

Hardness Test:

Surface of pin - Rockwell "B" 82.

Microstructure:

Apparent grain size 7 to 8. Annealed structure of blocky ferrite and fine pearlite. Surface has partial decarburization 0.010" deep.

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Spring - Steering Clutch

The springs were coiled of spring wire of the approximate grade FS 1070.

Chemical Analysis:

C	0.72%	Si	0.22
Mn	0.63	Cr	0.04
P	0.021	Ni	0.20
S	0.029	Mo	0.04
		V	None

Physical Tests:

Load at 3-1/4" - 57.5, 57.7, 57.3, 57.0 pounds
Solid Height - 2-3/8"
Bend Test - Satisfactory
Hardness on wire - Rockwell "C" 43-44

Surface Examination:

Springs examined were free from surface defects except for small die mark on wire inside one spring. It is doubtful that any shot peening had been done on the spring.

Steering Clutch Disc

The clutch discs or rings with internal teeth for the drive discs and external teeth for the driven discs were machined from steel of the approximate composition F.S. 1080. The I.D. and O.D. were turned, the teeth were shaper cut and the face was ground on both sides. The discs were heat treated to a hardness range which remained Rockwell "C" 35-40 after service.

Chemical Anaylsis:

C	0.85%	Si	0.22%
Mn	0.69	Cr	0.13
P	0.029	Ni	0.20
S	0.037	Mo	None

Hardness Tests:

	Pitch line of teeth	Rim
Drive Disc	R"C" 35	35-37
	35	34-36
	38-40	39-40
Driven Disc	39	39-41
	32	34-35
	34	32-36

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Profilometer readings of disc surface in microinches.

	Original Finish	Smoothest Area from wear	Average wear track
Drive Disc	100-120	15-20	20-30
	180-220	15-50	30-40
	40- 50	15	30
Driven Disc	120-140	15-25	30-40
	80-100	15	30-40
	170-190	15-20	20-30

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FINAL DRIVE PARTS

Final Drive Gear

The final drive gear was forged from Krupp steel. The analysis is shown in Table VIII. The gear was machined, carburized all over and hardened except for the bore. It was then shot blasted and the finish grinding operations performed. Flats were worn on both sides of the teeth at the pitch line. Photograph 1008.4

Hardness Test:

Surface of tooth	Rockwell "C" 61-62
Center of tooth at pitch line	Rockwell "C" 34
Center of tooth at root	Rockwell "C" 33
Core of gear (web)	B.H.N. 321

10 Kg. Vickers traverse near pitch line of tooth.

Distance from Edge	Converted to Rockwell "C"
0.010"	59
0.020	58
0.030	55
0.040	50
0.050	42
0.060	39
0.075	36
0.090	34
0.135	34

The gear teeth, rim and web, are file hard. The hub, bearing seat and internal splines are only file resistant.

Microstructure:

Case depth at pitch line 0.040"
Case - Martensite with excessive carbides at the surface.
Core - Low carbon martensite with transformation products including ferrite.
Profilometer reading on teeth: - 90-120 micro inches.

Final Drive Pinion

The final drive pinion was forged from Krupp steel in such a manner that the flow lines show the stock bent to form the tooth section. The analysis is shown in Table VIII. The pinion was machined, carburized all over and hardened. It was then shot blasted and the finish grinding operations performed. The teeth were worn and pitting had occurred at the bottom of the tooth face. Photograph 1008.4

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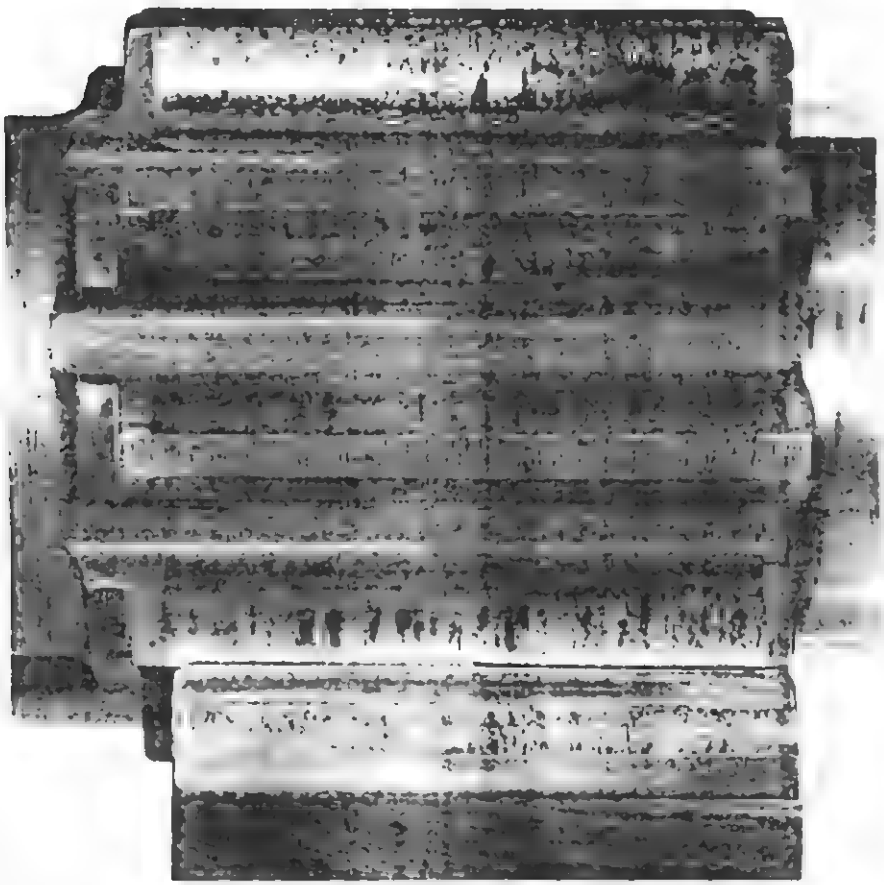

1008.4 - FINAL DRIVE PINION AND BULL GEAR SECTION

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Hardness Test:

Surface of tooth	Rockwell "C" 61
Bearing surface	Rockwell "C" 57-59
Top of spline	Rockwell "C" 50
Core of pinion	B.H.N. 430
Bore of pinion	File hard

A Russian brinell impression had been made on the spline end of the shaft with a rough grind preparation.

Microstructure:

Case depth at pitch line 0.030"
Case depth at root 0.030"
Case - Martensite with excessive carbides, possibly low temper.
Core - Marsenite and transformation products.

Axle - Drive Shaft

The drive shaft was machined from Krupp steel. The analysis is shown in Table VIII. The shaft was machined and then heat treated by means of a quench and draw. Following this, the shaft was cleaned and the final grind operations performed.

Hardness Test:

Surface of spline	Brinell 364
Core of shaft	Brinell 364

The hardness tests show this hollow bored shaft to be hardened through.

A Russian brinell impression had been made on the surface of the shaft in the center of the length.

Microstructure:

The structure is uniform throughout the section and shows the effect of a high temper following the quench.

Speedometer Drive Pinion

The pinion was machined all over from a heat treated bar length of steel. The ends of the pinion shaft run in bronze bushings. The pinion is driven by a bronze worm ring keyed to the final drive hub and flange.

Hardness Test:

Teeth - Not file hard.
Bearing surface of shaft - Rockwell "C" 30-33.

Track Drive Wheel

The drive wheel is a steel casting of a medium carbon, chromium, nickel, composition for which there is no exact American specification. The analysis is shown in Table VIII.

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Hardness Test:

Near and far plate (or rims) - both locations B.H.N. 207

Microstructure:

Carbides are spheroidized, probably the result of a high temper on fine pearlite and bainite obtained on quenching the wheel.

Track Drive Wheel Roller

The roller was forged from a medium carbon, chromium, silicon, nickel steel of no comparable American specification. The analysis is shown in Table VIII. The roller was hardened by quenching and drawing with no special effort to harden the surface.

Hardness Test:

Surface of hub - B.H.N. 418

Microstructure:

Martensite, acicular ferrite and transformation products.

Track Drive Wheel Roller Pin

The roller pin was machined from a medium carbon, chromium, silicon, nickel steel of no comparable American specification. The analysis is shown in Table VIII. The surface of the pin was hardened, possibly by induction or flame, judging from the sharp line between the case and core. The pin was worn eccentrically, from an initial size of 1.505", to 1.460" on the diameter of maximum wear and to 1.500" on the diameter of least wear.

Hardness Test:

Surface - Rockwell "C" 55 - This hardness is normal for the treatment.
Core - B.H.N. 241

Microstructure:

Case depth - 0.100" by surface hardening.
Case - Martensite. No evidence of tempering.
Core - Dense pearlite and blocky ferrite.

Track Adjusting Worm

The worm was probably a forging and the material was a medium carbon, chromium, silicon, nickel steel of no comparable American specification. The analysis is shown in Table VIII. The worm was quenched and drawn after machining. It appears to have been cleaned by sand blasting and then the bearing surfaces were ground.

Hardness Test:

Surface of worm	Rockwell "C" 43-44
Bearing surface	Brinell 444

There was a Russian brinell impression on the end of the shaft at the square end.

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Track Adjusting Worm Gear

The gear was probably a forging and the material was a medium carbon, chromium, silicon, nickel steel of no comparable American specification. The analysis is shown in Table VIII. The gear was machined all over, probably as normalized, and there was no subsequent heat treatment. The teeth of the gear showed severe wear from the action of the harder worm.

Hardness Test:

Surface of gear	Rockwell "C" 29
Surface of hub	Brinell 286.

Track Adjusting Worm Bushing Flange

The flange was probably hot formed in a press from medium carbon steel with no subsequent heat treatment. The estimated carbon content is 0.40-0.45%.

Hardness Test:

Rockwell "C" 9-10

Microstructure:

Coarse grained pearlite with ferrite grain boundaries. Grain size 2-4.

Track Adjusting Worm Bushing

The bushing was machined from pearlitic cast iron which showed a small amount of ferrite. The material appears to have been adequate for the application.

Track

The single pin track was cast from Hadfield manganese steel. The analysis is shown in Table VIII. This composition conforms to the customary limits except for the silicon which is higher, on two parts analyzed, than the nominal 0.030-1.00%. The silicon content of the used track with crest, 2.34%, which was sampled, is at the upper limit for producing a moderate increase in yield strength and resistance to plastic flow under repeated stress.

A flat track which had not been in service, had a silicon content of 1.70% This is in the range where these beneficial properties are obtained.

The principal applications of Hadfield steel are where heavy impact and a large factor of safety are the considerations. Typical examples of this use are in rock crushing machinery, railroad crossings and the tips of power shovel buckets.

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Hardness Tests:

Flat Track - Flat surface - Brinell 202
Track with crest - Flat surface - Brinell 217
Tip of crest - Brinell 495.

The hardness readings obtained on the flat surfaces are normal for castings following the toughening heat treatment. The high hardness obtained on the crest is typical for this steel after work hardening.

A Russian brinell impression was observed on a track pin lug.

Track Pin

The track pin has an upset head on one end and the other end is as sheared from a steel bar. The material was a medium carbon, chromium, silicon, nickel steel of no comparable American specification. The analysis is shown in Table VIII. The pieces were heat treated to produce a high hardness.

Hardness Tests:

Surface of pin	Brinell 555 (2 pins)
	Rockwell "C" 50
Core of pin	Rockwell "C" 53

Microstructure:

Martensite and some transformation products with no distinct evidence of a drawing treatment. The surface was partially decarburized to a depth of 0.009" which accounts for the reduced hardness there. The pin was hardened through the 3/4 inch section.

The hardness of the pins was duplicated by quenching in water from 1600°F, followed by a draw at 350°F for one hour. The quenched hardness was Brinell 578.

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FERROUS METALLURGY
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TABLE VIII

FINAL DRIVE PARTS

Part Name	C	Mn	P	S	Si	Cr	Ni	Mo	Case Depth	Hardness O.D.	Hardness Core	Ht.
Gear - Final Drive	.14	.43	.018	.028	.17	1.57	3.50	.10	.040"	61	33	Carb.
Pinion - Final Drive	.19	.38	.022	.021	.39	1.46	4.09	.32	.030	61	430	Carb.
Axle Shaft	.17	.50	.022	.022	.23	1.27	4.35	.22		364	364	Q & T
Track Drive Wheel	.30	.84	.042	.032	.22	.73	.45	.04		207		Q & T
Roller, Drive Wheel	.39	.56	.032	.027	1.10	1.54	.34	.04		418		Q & T
Pin, Drive Wheel Roller	.37	.46	.029	.031	1.21	1.69	.16	.03	.100"	55	241	Flame
Worm - Track Adj.	.33	.45	.025	.022	1.09	1.39	.30	.0[illegible]		444		Q & T
Gear - Track Adj.	.38	.55	.027	.029	1.18	1.73	.17	None		29		Q & T
Track	1.09	10.5	.094	-	2.34/1.70	.58	.31	.20		202		
Track Pin	.36	.36	.022	.034	1.18	1.69	.28	.05		555		Q & T

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SUSPENSION PARTS

Suspension Spring

The suspension spring was made of silicon manganese steel of the same composition as F.S. 9260. The analysis is shown in Table IX. The springs were coiled from hot rolled round bars, which had a poor surface condition, with rough flats and guide marks. The springs were hardened through to spring hardness.

Hardness Tests:

Surface	Brinell 477
Core	Brinell 444

Hardness Traverse on cross section -
Rockwell "C" 47, 46, 45, 46, 45.5, 46, 46, 46, 46, 47, 46.5, 46, 47, 46.5

A Russian brinell impression was noted on the center coil of an outer spring which had been made on a deep rough ground spot.

Microstructure:
Normal quenched and drawn structure.

Suspension Shaft (Photograph 1301.1 in main body of report)

The suspension shaft was forged from a medium carbon, chromium, silicon, nickel steel of no comparable American specification. The analysis is shown in Table IX. The shaft was hardened through by heat treatment before machining.

Hardness Tests:

Bearing seats at ends of shaft	Brinell 269, 269
Surface at mid length of shaft	Brinell 262
1/2 radius, this location	Brinell 262

Suspension Arm Wheel Spindle (Photograph 1301.1 in main body of report)

The wheel spindle was forged from a medium carbon, chromium, silicon, nickel steel of no comparable American specification. The analysis is shown in Table IX. The shaft was hardened through by heat treatment before machining.

Hardness Test:

Bearing seats at ends	Brinell 262, 269
Surface at mid length of spindle	Brinell 277
1/2 Radius this location	Brinell 248

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Lower Suspension Spring Retainer Stud
Photograph 1301.1 in main body of report)

The stud was forged from a medium carbon, chromium, silicon, nickel steel of no comparable American specification. The analysis is shown in Table IX. The stud was hardened through by heat treatment before machining.

Hardness Test:

Surface at retainer end	Brinell 277
1/2 Radius this location	Brinell 248
Surface at mid length of stud	Brinell 269
1/2 Radius this location	Brinell 269
Surface at suspension arm end	Brinell 277

Front Wheel Spring Anchor Arm (Photograph 1301.0)

The anchor arm was forged from a medium carbon, chromium, silicon, nickel steel of no comparable American specification. The analysis is shown in Table IX. The shaft was probably machined or forged with no heat treatment.

Hardness Test:

Surface of boss at each end	Brinell 241

Suspension Arm (Photograph 1301.1)

The suspension arm is a hollow steel casting of approximately one inch wall thickness. The composition is a medium carbon, chromium, nickel steel for which there is no exact American specification. The analysis is shown in Table IX. The arm appears to have been used as cast or possibly annealed. There has been no attempt to improve the physical properties of the arm by heat treatment.

Hardness Test:

Surface of arm	Brinell 196
Center of cross section	Brinell 207

Suspension Arm Thrust Plate (Photograph 1301.1)

The thrust or guide plate was sheared from plain low carbon steel plate of the same composition as F.S. 1020. The analysis is shown in Table IX. Three holes were drilled in the plate for attaching it to the hull.

Hardness Test:

Surface of plate	Brinell 131

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Suspension Trunnion Block Pin (Photograph 1301.1)

The pin was made of cold drawn bar steel of the same composition of AISI 1037. The analysis is shown in Table IX. The bar stock for the pins was annealed, but there was no other heat treatment.

Hardness Test:

Surface of pin	Rockwell "B" 93, 90-92
Core of pin	Brinell 196, 196

Microstructure:

Blocky ferrite and pearlite. Grain size 7 to 8.

Suspension Spring Trunnion Block

The trunnion block was sheared from steel plate of the same composition as F.S. 1035 with no heat treatment. The analysis is shown in Table IX.

Hardness Test:

Surface of block	Brinell 163

Microstructure:

Block ferrite and medium pearlite.

Suspension Spring Guide Rod Bushing

The bushing was made of cast iron with no hardening treatment. The turned surface is rough.

Hardness Test:

Rockwell "B" 94 - O.D.
94 - I.D.

Microstructure:

Pearlite and graphite (Type A - Size No. 5)

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TABLE IX

SUSPENSION PARTS

Part Name	C	Mn	P	S	Si	Cr	Ni	Mo	Hardness Surf.	Hardness Core	Ht.
Suspension Spring	.61	.76	.024	.027	2.04	.09	.16	None	477	444	Q & T
Suspension Shaft	.34	.47	.025	.020	1.05	1.51	.22	.03	269	262	Q & T
Wheel Spindle	.34	.38	.018	.016	1.09	1.51	.22	.03	277	248	Q & T
Stud - Lower Spg. Ret.	.39	.48	.021	.016	1.14	1.58	.32	.04	277	269	Q & T
Arm - Front Wheel Spg. Anchor	.33	.37	.022	.019	1.13	1.53	.27	.06	241		
Susp. Arm.	.31	.75	.029	.028	.27	.74	.68	.07	196	207	
Thrust Plate - Susp. Arm	.22	.50	.035	.048	.10	.13	.12	None	131		
Pin - Trunnion Block	.38	.43	.026	.035	.23	.07	.27	None	' B " 93	196	
Block - Trunnion	.35	.60	.050	.040	.25	.04	.15	None	163		

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MISCELLANEOUS BOLTS, SCREWS, NUTS AND WASHERS

Bolt - Engine Hold Down

The bolt has 0.545" diameter shank by 5-1/2" long. The end of a cold drawn bar was hot upset to form a 7/8" hex head. The flash was cold trimmed from the bottom of the head. The end of the shank and underside of the head were rough turned. Threads were cut and the cotter pin hole drilled.

The composition of the steel used is:

C	0.42%	Si	0.36%
Mn	0.71	Cr	0.93
P	0.029	Ni	0.15
S	0.026	Mo	None

This approximates the specification for FS 5140.

Hardness Test:
Surface - Rockwell "C" 30, 29-30

Microstructure:
Dense pearlite with a small amount of ferrite in the grain boundaries. Grain size medium, no decarburization on threads. This structure indicates a fast cool from the hot rolling operation with no subsequent heat treatment.

Washer - Engine Hold Down Bolt

The washer was made by machining from 1" O.D. round bar stock. The I.D. is 5/8" and the thickness of the washer is 1/8". Low carbon bar stock was used of approximately 0.15% carbon.

Hardness Test:
Surface - Rockwell "B" 93 to 95.

Microstructure:
Blocky ferrite and pearlite with directional properties visible in the grains. There was no heat treating on the part.

Studs and Nuts - Oil Pan

The studs are 5/16" x 1-9/16" machined with cut thread from round bar stock and then heat treated. The nuts were machined from 17/32" hex and likewise heat treated.

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The chemical analysis is:

	Studs	Nuts
C	0.46%	0.45%
Mn	0.66-0.62	0.56
P	0.023	0.039
S	0.035	0.034
Si	0.27	0.18
Cr	0.10	0.25
Ni	0.10	0.13
Mo	0.02	0.01

This composition corresponds approximately to FS 1045 with residual chromium and nickel present.

Bolt - Transmission Drive Gear

The bolts were machined from bar stock of medium carbon, chromium, nickel, silicon steel. The round, flat slotted head is 1-1/32" O.D., the shank is 0.632" and the length of the bolt is 2-3/8". The machining on the bolt is rough. The head is undercut and the slot is off center. The threads were cut, the cotter pin holes were drilled and chamfered and the threads rechased. After heat treatment, the shank was ground.

The analysis of the steel used is:

C	0.43%	Si	1.20%
Mn	0.37	Cr	1.54
P	0.021	Ni	0.27
S	0.022	Mo	0.06

There is no comparable American specification for this composition.

Hardness Test:

Surface readings on the shank of three of the twelve bolts used were:

1 - Rockwell "C" 37
2 - Rockwell "C" 25
3 - Rockwell "C" 29

This is a somewhat wider range in hardness than used in ordinary practice for this class of bolt.

Nut - Transmission Drive Gear Bolt

The castellated nut was machined from 1-1/16" hex bar stock and was not heat treated. The composition, shown below, does not correspond to FS 1040 in that the manganese content is low.

C	0.41%	Si	0.18%
Mn	0.41	Cr	None
P	0.046	Ni	0.21
S	0.029	Mo	None

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Hardness Test:
Brinell 231 from Rockwell "B"

Microstructure:
Blocky pearlite and ferrite.

Cap Screw - Final Drive Housing to Hull

The cap screw is 3/4" x 2-7/16" and was upset to form the head. The composition shown below, corresponds to FS 1040 with residual chromium.

C	0.41%	Si	0.28
Mn	0.60	Cr	0.20
P	0.38	Ni	0.09
S	0.49	Mo	None

Hardness Test:
Brinell 170, 185, 190.
This hardness indicates there was no heat treatment on the bolt.

Cap Screw - Final Drive Housing to Hull Thru Pinion Bearing

The cap screw is 7/16" x 2-1/2" and was upset to form the head. The composition shown below, corresponds to FS 1020 steel.

C	0.18%	Si	0.27
Mn	0.50	Cr	0.13
P	0.015	Ni	0.15
S	0.050	Mo	None

Hardness Test:
Rockwell "B" 80 to 82, 74 to 76, 77.
There was no heat treatment on the screw.

Cap Screw and Spring Lockwasher, Suspension Thrust Plate to Hull

The cap screw is 3/4" x 2-3/16" and was upset to form the head. The cap screw was made of a composition corresponding to FS 1015 and the washer from FS 1060. The residual alloys in both these parts are high and may have been outright additions. The analysis is shown below:

	Cap Screw	Lockwasher
C	0.17%	0.59%
Mn	0.51	0.93
P	0.026	0.018
S	0.042	0.032
Si	0.03	0.23
Cr	0.21	0.24
Ni	0.21	0.18
Mo	None	0.07

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Hardness Test:

Capscrew — Brinell 118, 120 (300/2000 Kg.) on head. Brinell 131 (2000 Kg.) on body.

Lockwashers - Bend Test OK

Rockwell "C" 49 to 50 on two washers, one of which was broken.

The wide range in hardness on these three lockwashers, tested, indicates lack of close control to obtain spring hardness on heat treatment.

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ANTI FRICTION BEARINGS - BALL AND ROLLER

Four bearing assemblies of this type were given metallurgical examination; two each of ball and roller bearings. A large and small bearing of each kind were selected as representative of those of Russian make used in the vehicle. The bearing races, balls and rollers were made of high carbon, chromium steel with varying small fractional percentages of nickel of the approximate composition FS E52100 or FS E51100 and hardened through. Both of the large bearings were made of the higher chromium FS E52100 and the smaller bearings were made of FS E51100 except for the inner race of the small ball bearing.

The composition and properties of the bearings are shown in Table X. The micro-structure of the races and rollers or balls is similar for all of the bearings and consists of small spheroidal carbides in a martensite matrix. They may possibly have been a low temper.

See also the Appendices of this report entitled:
Ball and Roller Bearings - List

[redacted]

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FERROUS METALLURGY
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TABLE X

ANTI FRICTION BEARINGS

	Outer	Inner	Roller	Outer	Inner	Roller	Retainer	Outer	Inner	Ball	Outer	Inner	Ball
Type of Bearing	Tapered Roller			Tapered Roller				Ball			Ball		
O.D. of Race				5-1/2				6-11/16			1-27/32		
I. D. of Race	5-29/32			3-1/8				3-1/8			21/32		
No. of Balls or Rollers	17			17				8			7		
Size of Balls or Rollers			1-3/16 x 1-1/2			9/16 x 5/8				1-1/16			11/64
C	1.14	0.99	1.19	0.87	1.00	1.00	0.34	1.01	1.00	0.98	1.14	0.97	
Mn	0.30	0.42	0.38	0.31	0.25	0.40	0.60	0.36	0.26	0.35	0.34	0.33	
P	0.23	0.022	0.020	0.027	0.018	0.020	0.042	0.022	0.031	0.027	0.022	0.024	
S	0.18	0.022	0.012	0.013	0.024	0.013	0.024	0.017	0.23	0.024	0.026	0.026	
Si	0.25	0.27	0.27	0.22	0.30	0.24	0.19	0.21	0.19	0.22	0.25	0.26	
Cr	1.45	1.49	1.45	1.15	0.99	0.83	None	1.72	1.50	1.32	0.74	1.68	
Ni	0.19	0.12	0.27	0.23	0.25	0.18	0.11	0.34	0.33	0.37	0.11	0.10	
Mo	0.04	0.05	0.06	0.04	0.05	0.04	0.03	0.04	0.04	0.04	None	None	
Surface Hardness R"C"	62-63	61-63	64	60	60-61	63-64	R"B" 80	62	62	61-62 File Hard	61	62	File Hard
Core	61	62	59.5	60	60	63	R"B" 83	62	63		61	62	
Location Used	Final Drive Gear			Transmission Main Shaft				Bogie Wheel			Water Pump Shaft		

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METALLURGY

Non-ferrous

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NON-FERROUS METALLURGY REPORT

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Subject: Metallurgical Analysis of Non-Ferrous Components in T34 Tank

Conclusions: On basis of this investigation it was generally found that:

1 - Choice and quality of non-ferrous alloys used in the T34 tank applications were satisfactory.

2 - Chemical composition of T34 parts indicated that primary metal or a high grade of scrap was employed by the manufacturer.

3 - T34 non-ferrous components revealed that the quality of workmanship and condition of manufacturing equipment were consistently below normal standards associated with good industrial practice. However, this condition did not seriously reflect on the serviceability of the parts.

4 - The non-ferrous materials in the T34 tank were comparable to non-ferrous alloys commonly employed in United States and Western Europe.

Parts Examined: Parts analysis contained in this report was confined to the non-ferrous components used in the engine and accessories of the T34 tank. Essentially three basic alloys constituted the non-ferrous materials in the tank.

They are as follows;

Section A - Aluminum Alloys
Section B - Zinc Alloys
Section C - Copper Alloys

Attention is also called to the use of tungsten in an electrical contact.

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SECTION A - ALUMINUM ALLOYS

The T34 tank made extensive use of aluminum in the engine and accessory parts. Approximately one thousand pounds of aluminum alloys were found in the form of castings, forgings, and wrought bar and sheet stock. See Table I for a detailed list of the form, chemical composition, and weight of each of the parts. As the bulk of aluminum used was in cast form, the following captioned paragraphs contain general discussion on the various aspects associated with foundry practice and procedure as reflected in T34 tank castings.

Metal Quality: Particular attention was devoted to the quality of metal used in the castings. Both X-ray and macro examination indicated sound metal structure of good uniform grain size in the cast components. This condition suggested the possibility that some type of modifying agent or grain refinement had been employed. However, chemical analysis failed to support this contention conclusively.

Finishing: This section refers to the amount of cleanup and the manner in which it was done in addition to the general appearance of the exterior parts. In this respect, the permanent mold castings were found to be in fair to poor condition. Heavy parting lines due to improper closing of the molds were noted. This caused excessive formation of flash which could only be removed by considerable cleanup, an operation both time consuming and costly. Also, the crude manner in which the cleanup was done as noted by the tool marks on the parts showed a certain degree of carelessness on the part of the workman or lack of proper cleanup methods. Exterior surfaces were generally rough, reflecting rough mold surfaces and improper finishing operations.

Foreign Inclusions: Core wires and sand inclusions were revealed in many of the sand castings and semi-permanent mold castings. Also, the effects of soft ramming, inferior mixes and rough handling of cores and molds were noted. These factors indicated that the quality control of the sand in the foundries was inferior to our accepted standards.

Chaplets: One instance where chaplets were employed to hold the sand cores in position resulted in severe segregation, cracking, and porosity in their adjacent areas.

Design: Castings were designed with suitable fillets and proper blending of the thin and heavy sections. Also, extensive use was made of cross hatching permanent mold sides in order to make the metal lie quiet during the casting process. This is considered good practice and is used to promote better surface condition in many castings.

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Heat Treatment: Hardness values indicated that good heat treating practice was being observed in fabrication of the castings. However, it is believed that many of the accessory castings not requiring maximum mechanical properties were unnecessarily heat treated thus adding to production costs.

To avoid repetition during the discussion of each of the individual parts, the following general comments are applicable to each of the groups of non-ferrous aluminum alloys used in the T34 tank.

Group I

Aluminum-Silicon-Magnesium Alloys

The chemical composition of these alloys ranges between these limits:

Silicon	5-13%
Iron	.7%
Magnesium	.2-.7%
Manganese	0-.6%
Aluminum	Balance

The majority of aluminum components both by weight and number used in this tank engine were cast from a modified silumin alloy. This alloy, common to European practice, contained 8-10% silicon and 0.3% magnesium. The silicon content is approximately 1% above the maximum limits specified for silicon in the Alcoa 356 alloy and slightly more than this for Alcoa 355 alloy, however, it is common practice to consider all of these alloys in the same category.

The cylinder block with its many cored passages is a good example of an intricate casting illustrating the excellent castability of the alloy. This material also provides a good combination of resistance to corrosion and pressure tightness. It is used in casting applications receiving severe usage. It responds readily to heat treatment, with various combinations of mechanical properties obtainable by solution heat treatment and artificial aging. This alloy was used to good advantage in sand, permanent mold, and semi-permanent mold castings for numerous components in the T34 tank engine as indicated in Table I.

Group II

Aluminum - Copper Casting Alloys

The ranges for the usual chemical composition of these alloys are:

Copper	6-8%
Iron	0.3-1.5%
Silicon	0.3-4.0%
Zinc	0-2.5%
Aluminum	Balance

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Alloys in the above ranges are usually produced from secondary material which accounts for the presence of manganese, nickel and other common impurities generally found in aluminum. At one time, alloys in this range constituted a large portion of our production. Some of the better known designations are Alcoa's 112-113 or No. 12. It is employed in intricate casting designs where pressure tightness is a requisite. Machinability is good. The alloy is heat treatable but more often is used without any treatment because the improvement in mechanical properties does not warrant the additional cost in many instances. A good application of this alloy was shown in the air cleaner to intake manifold elbow casting.

Group III

Aluminum-Copper-Zinc Alloys

Chemical composition of these alloys ranges between the following limits:

Copper	1-4%
Iron	Max. 1.5%
Manganese	0-1%
Nickel	0-1%
Silicon	Max. 3%
Zinc	4-15%
Aluminum	Balance

Referred to as the German alloy, this alloy has good castability, high strength, and ductility and was satisfactorily used in the production of the upper and lower transmission cases. It functions as an intermediate alloy between aluminum-copper and aluminum-silicon alloys. With zinc the alloy age hardens rapidly at room temperature with resultant losses in ductility. Also, these alloys are considered to be hot short if the iron and silicon content is low and as such should not be cast in a permanent mold. A comparable aluminum alloy specified within this composition range would be Alcoa 645.

Group IV

Aluminum-Copper-Silicon

Chemical composition ranges between:

Copper	2-6%
Silicon	3-6%
Iron	1%
Aluminum	Balance

Alloys within this range compared to the Alcoa 85 alloy used in die casting applications, having excellent castability with a low shrinkage coefficient,

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particularly suited to parts which must withstand high pressure in service. Although classed here as die casting alloys, they can be used for permanent mold castings such as in the T34 fuel transfer pump. Machinability is generally considered inferior to the aluminum-copper alloys.

Group V

Aluminum-Copper-Nickel

Chemical composition ranges between:

Copper	3-5%
Nickel	1-2.5%
Magnesium	.5-2.0%
Iron	.7%
Silicon	.7%
Aluminum	Balance

Alcoa 142 alloys of the "Y" alloy type fall within this wide classification. These alloys have high mechanical properties in the as cast and heat treated condition. Alloys in this group are often used for forging stock as in the case of engine pistons because of the good hot strength properties imparted by the nickel and the general good forging characteristics of this material.

Group VI

Duralumin Alloys

Chemical composition ranges between:

Copper	3-5%
Iron	Max. .8%
Magnesium	.3-2.0%
Manganese	.3-1.5%
Silicon	.2-1.5%
Aluminum	Balance

Group VII

Miscellaneous Aluminum Alloys

One part to be included in this category was the water filler and pressure cap housing which apparently was composed of a high zinc (25.4%) copper (3.2%) alloy. The large amount of impurities present indicated that this alloy was of a secondary nature melted down from scrap containing high zinc and copper. The corrosion rate of such an alloy increases as the zinc content increases and as such is not considered to be very satisfactory when exposed to a corrosive environment.

The remainder of this section is devoted to the detailed examination of each of the aluminum parts.

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Part Name Camshaft Bearing Block

Laboratory Serial No. 262056 Date

X-RAY EXAMINATION: XCED NO. H-025 and H-215 - Revealed shrink and porosity in center web section at junction of heavy to thin sections of 10 blocks. Fair quality.

MACRO EXAMINATION: Photograph 6372B, shows medium uniform grain structure with location of porosity in thin to heavy section.

CHEMICAL ANALYSIS: Si 8.7%, Cu 0.15%, Fe 0.51%, Mg 0.31%, Mn 0.43%, Ti /.1% Cr /.1%, Zn /.5%, Ni /.5%

25X1A Compares to Alcoa 356 alloy [redacted]

HARDNESS VALUE: 93 B.H.N. Weight of 0.92 Pounds

Finish Rough saw cuts where gate and risers had been trimmed.

COMMENTS: A. Workmanship Mold surfaces rough - Parting lines heavy indicative of poor closing of the mold.

B. Machining Aluminum bearing surfaces - machined and ground finished to 70-80 micro inches.

C. Design Quality Satisfactory - except a more suitable blending in web section might have eliminated shrink.

D. Manufacturing Method & Quality Permanent mold casting - B.H.N. value indicates heat treatment: sol'n Tr. and aged.

MICROSTRUCTURE: Aluminum - Silicide constituent well dispersed, also magnesium silicide, which makes this alloy heat treatable.

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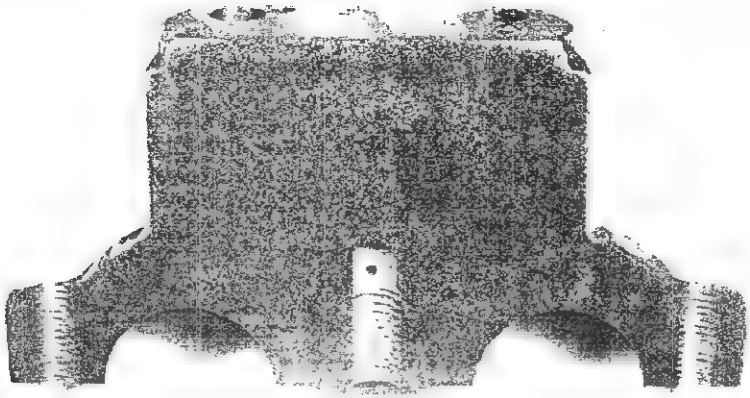

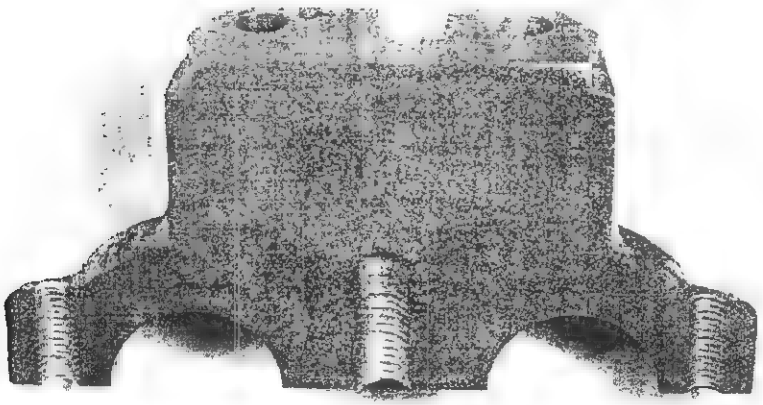

6372 B MACRO SECTION OF CAMSHAFT BEARING BLOCK

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Part Name Camshaft Bearing Cap

Laboratory Serial No. 262056 Date

X-RAY EXAMINATION: XCED NO. H-025 and H-215 Showed no apparent shrink or porosity in 10 caps inspected - Good quality.

MACRO EXAMINATION:

CHEMICAL ANALYSIS: Si 8.7%, Cu 0.15%, Fe 0.51%, Mg 0.31%, Mn 0.43%, Ti /.1%, Cr/.1%, Zn /.5%, Ni /.5%

Compares to Alcoa 356 [redacted] 25X1A

HARDNESS VALUE: 93 B.H.N Weight of 0.42 Pounds

Finish Rough saw cuts where gates and risers and flash had been trimmed.

COMMENTS: A. Workmanship Mold surfaces rough. Good workmanship on the vital areas i.e. bearing areas.

B. Machining Rough chamfers - Aluminum bearing surface machined and ground to 70-80 micro inches.

C. Design Quality Satisfactory

D. Manufacturing Method & Quality Permanent mold casting - Good quality - B.H.N. value indicates heat treatment. Sol'n treat and aged.

MICROSTRUCTURE: Aluminum silicide constituent uniformly disperesed Also magnesium silicide, which makes this alloy heat treatable.

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Part Name Oil Pump Body (4 sections)

Laboratory Serial No. 263104 Date

X-RAY EXAMINATION: XCED NO. H-145 - One of the four parts had shrinkage in center body section at junction of thin to heavy area - Good quality.

MACRO EXAMINATION: Macro inspection, photograph 6404, exhibited a uniform fine grain size in all four segments.

CHEMICAL ANALYSIS: Si 8.2%, Cu /.6%, Fe .53%, Mn .27%, Mg .23%, Ni /.5%, Zr /.04%, Cr. 05%, Zn /.5%, Ti /.4%

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: 89-96 B.H.N. Weight of 4.62 Pounds

Finish Rough cleanup on exterior portions of pump body - Tool marks.

COMMENTS: A. Workmanship Mold surfaces rough - Heavy parting lines indicative of improper closing of molds.

B. Machining Ground finish on surfaces of flanges and interior pump faces - 35 to 40 micro inches.

C. Design Quality Satisfactory - Although some grossness exists in many sections.

D. Manufacturing Method & Quality Permanent mold casting - Good quality - B.H.N. value indicates heat treatment - Sol'n. tr. and aged.

MICROSTRUCTURE: Aluminum silicide in medium form thru matrix. Slight amount of acicular Al-Fe-Si noted. Mg. appears to be all in solid solution.

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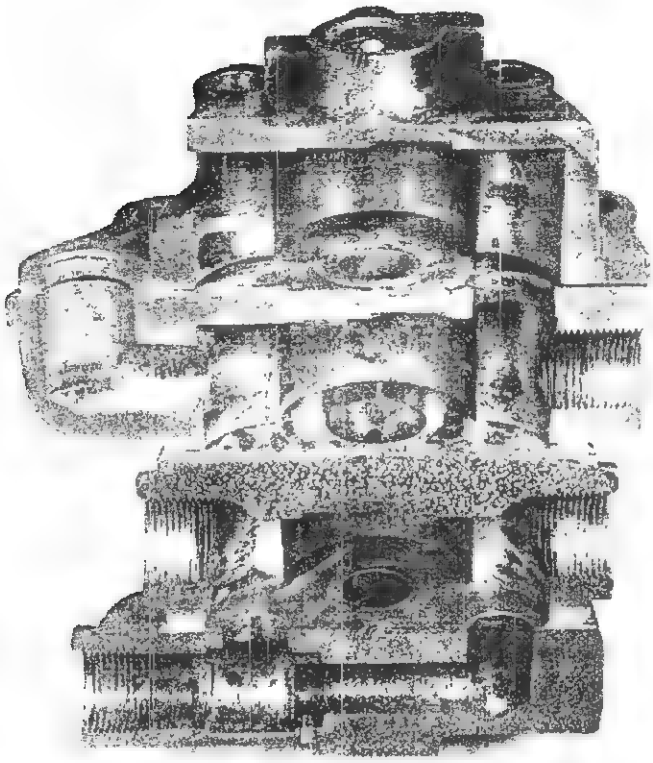

6404 - MACRO SECTION OF OIL PUMP BODY - T34 ENGINE

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Part Name Camshaft Drive Pinion Bearing Support

Laboratory Serial No. 263105 Date

X-RAY EXAMINATION: XCED NO. H-152 - No porosity or shrinkage noted during radiographic inspection - Good quality.

MACRO EXAMINATION: Photograph 6405, showed a very fine uniform grain structure.

CHEMICAL ANALYSIS: Si 8.2%, Cu .6%, Fe .47%, Mn .24%, Mg .26%, Ni /.5%, Cr .04%, Zn /.5%, Ti /.05%, Zr /.05%

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: 96 B.H.N Weight of 1.56 Pounds

Finish Rough cleanup - Tool marks - presence of burned sand - poor finishing - Excessive cleanup.

COMMENTS: A. Workmanship Mold satisfactory - Sand cores showed signs of soft ramming - foreign inclusions (sand).

B. Machining Finish ground surfaces (40-50 micro inches on flanges and bearing areas.

C. Design Quality Ribs poorly blended to body - Wall sections heavily scribed good practice.

D. Manufacturing Method & Quality Semi-permanent mold cast-Good quality of metal - BHN value indicated Sol'n tr. and aged condition.

MICROSTRUCTURE: Aluminum silicide present in medium to coarse form in matrix.

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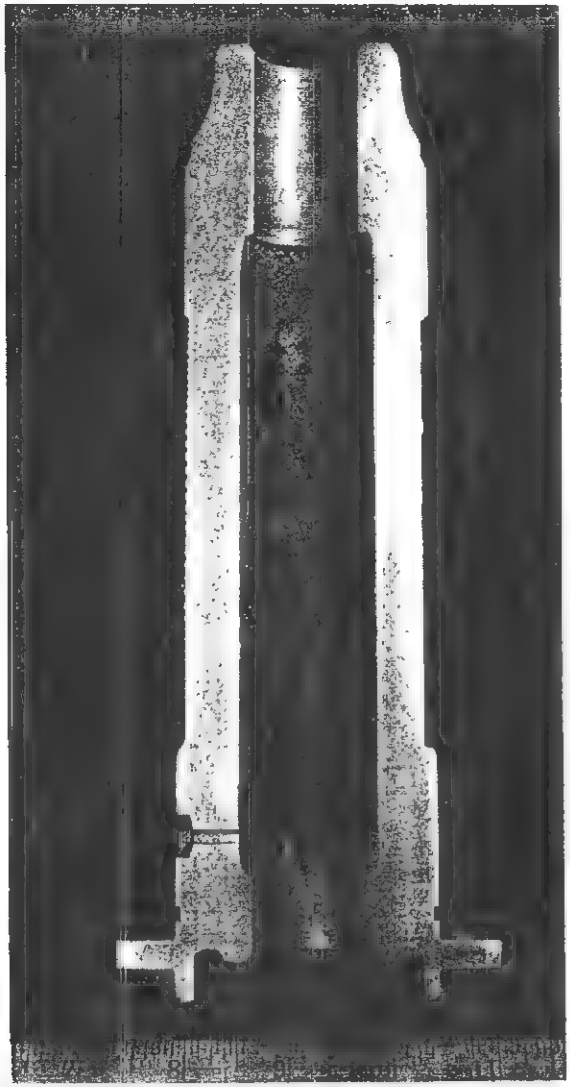

6405 - MACRO SECTION OF CAMSHAFT DRIVE PINION BEARING SUPPORT - T34 ENGINE

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Part Name Upper Accessory Drive Shaft Bearing

Laboratory Serial No. 263101 Date

X-RAY EXAMINATION: XCED NO. H-148 - No porosity or shrinkage detected by this method - Good quality.

MACRO EXAMINATION: Photograph 6406, showed a uniform dense structure - very good metal quality.

CHEMICAL ANALYSIS: Si 8.1%, Cu /.6%, Fe .49%, Mn .26%, Mg .23%, Ni /.5%, Cr /.05%, Zn /.5%, Ti /.05%, Zr /.05%

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: 100 B.H.N. Weight of 1.56 Pounds

Finish Heavy tool marks caused during core knockout. Rough saw cuts at riser and gating areas - burned sand.

COMMENTS: A. Workmanship Rough interior surfaces possibly due to poor sand coring practice i.e., soft ramming.

B. Machining Ground surfaces on flanges and bearing areas 25-35 micro inches.

C. Design Quality Grossness in design - poor blending of ribs to body.

D. Manufacturing Method & Quality Semi-permanent mold - Heavily scribed surfaces - Good quality of metal - BHN indicates solution heat treatment and aging.

MICROSTRUCTURE: Aluminum silicide in medium form dispersed thru matrix. Good normal structure.

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6406 - MACRO SECTION OF ACCESSORY DRIVE SHAFT BEARING

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Part Name Generator Coupling Drive Shaft Center Bearing

Laboratory Serial No. 263099 Date

X-RAY EXAMINATION: XCED NO. H-146 - Revealed shrink at junction of heavy flange to thin wall section of body. Some blows as gas holes and porosity - Fair quality.

MACRO EXAMINATION: Photograph 6407, showed a uniform fine grain size - dense sound structure.

CHEMICAL ANALYSIS: Si 8.7%, Cu /.6%, Fe .52%, Mn .28%, Mg .30%, Ni /.5%, Cr /.04%, Zn /.5%, Ti /.05%, Zr /.05%

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: 93 B.H.N. Weight of 1.42 Pounds

Finish Cleanup normal - Some evidence of tool marks and burned core sand.

COMMENTS: A. Workmanship Molds not closing properly as indicated by heavy parting line. Rough interior surfaces due to sand core erosion.

B. Machining Ground surfaces on bearing and flanged areas - 25-60 micro inches.

C. Design Quality Gross design in flange areas - Good blending of sections.

D. Manufacturing Method & Quality Semi-permanent mold casting - Good quality of cast metal - Scribed mold - BHN value indicates sol'n treat and aged casting.

MICROSTRUCTURE: Medium form of aluminum silicide constituent dispersed uniformly in matrix. Normal structure.

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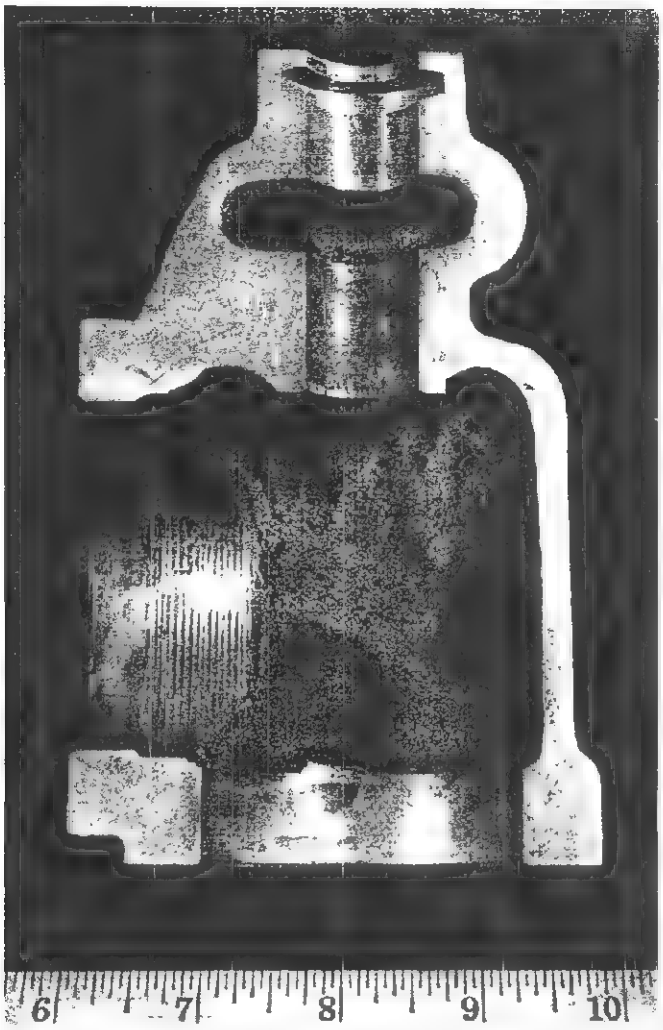

6407 - MACRO SECTION OF GENERATOR DRIVE SHAFT CENTER BEARING

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Part Name Lower Camshaft Drive Gear Bearing

Laboratory Serial No. 263102 Date

X-RAY EXAMINATION: XCED NO. H-149 Revealed a sound structure, no porosity or shrinkage detected. Good quality.

MACRO EXAMINATION: Photograph 6409, showed a uniform fine grain structure - Good quality.

CHEMICAL ANALYSIS: Si 8.3%, Cu /.6%, Fe .52%, Mn .20%, Mg .30%, Ni /.5%, Cr /.04%, Zn /.5%, Ti /.05%, Zr /.05%

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: 100 B.H.N. Weight of 1.80 Pounds

Finish Satisfactory cleanup - Tendency to leave more stock than normal machining allowance needs.

COMMENTS: A. Workmanship Heavy parting lines indicate mold not completely closed.

B. Machining Finish ground to 22-25 micro inches on all bushing and flange surfaces.

C. Design Quality Satisfactory - Good blending of sections - Could reduce section thickness.

D. Manufacturing Method & Quality Semi-permanent mold casting. Good quality casting - Scribed mold walls - B.H.N. value indicates solution treatment and age to Alcoa T6 condition.

MICROSTRUCTURE: Medium form of the usual aluminum silicide dispersed uniformly thru matrix. Normal structure.

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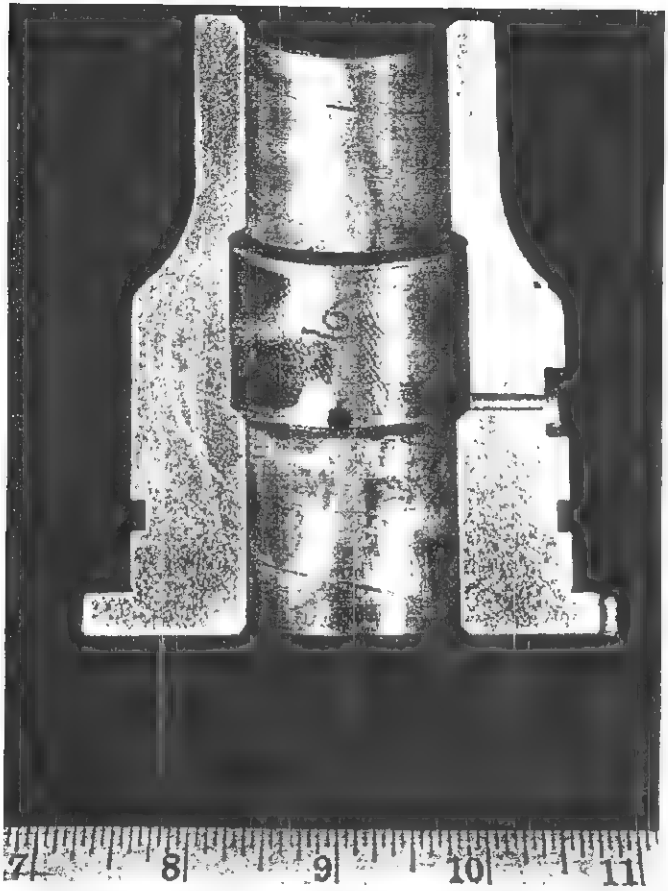

6409 - LOWER CAMSHAFT DRIVE GEAR BEARING - T34 ENGINE

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Part Name Generator Coupling Drive Shaft End Bearings

Laboratory Serial No. 263103 Date

X-RAY EXAMINATION: XCED NO. H-150 Revealed a very sound dense structure - No shrink - No porosity - Good quality.

MACRO EXAMINATION: Photograph 6408, showed a fine uniform grain structure - Good metal quality.

CHEMICAL ANALYSIS: Si 9.2%, Cu /.6%, Fe .60%, Mn .25%, Mg .30%, Ni /.5%, Cr /.04%, Zn /.5%, Ti /.05%, Zr /.05%

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: 100 B.H.N. Weight of 0.44 Pounds

Finish Satisfactory - little cleanup noted.

COMMENTS: A. Workmanship Mold appeared in good condition - workmanship satisfactory.

B. Machining Finish ground surfaces 45 to 50 micro inches on bearing areas - Stock left for machining allowances more than necessary.

C. Design Quality Satisfactory - Although heavy sections could be reduced and ribbed for strength.

D. Manufacturing Method & Quality Permanent mold casting - Flange areas of mold scribed - B.H.N. indicates solution treatment and aged to Alcoa T6 condition.

MICROSTRUCTURE: Medium form of aluminum silicide present, in matrix - Normal structure - Also evidence of aluminum iron - silicide constituent in acicular form.

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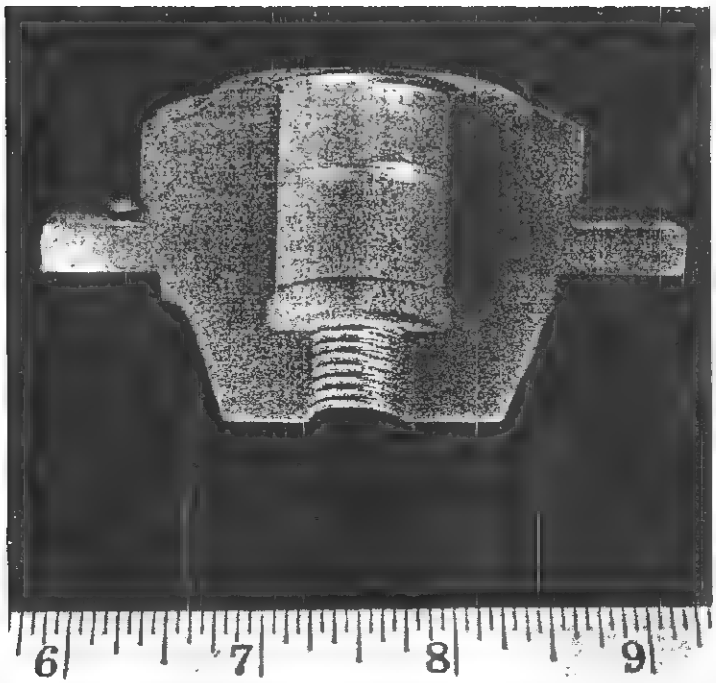

6408 - MACRO SECTION OF GENERATOR COUPLING DRIVE SHAFT END BEARING - T34 TANK ENGINE

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Part Name Generator Drive Shaft Bearing Sleeve

Laboratory Serial No. 263100 Date

X-RAY EXAMINATION: XCED NO. E-147 Revealed heavy porosity in front bearing area, also blows in form of gas holes: Fair quality.

MACRO EXAMINATION: Uniform fine grain size.

CHEMICAL ANALYSIS: Si 7.7%, Cu /.6%, Fe .60%, Mn .25%, Mg .30%, Ni /.3%, Cr /.05%, Zn /.5%, Ti /.05%, Zr /.05%

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: B.H.N. 74 Weight of 1.46 Pounds

Finish Excessive cleanup needed - tool marks - burned sand - Flash and heavy gates sawed off.

COMMENTS: A. Workmanship Mold not closing properly - Sand cores were poor resulting in washes and erosion.

B. Machining Ground finishes on bushing to 32-35 micro inches; on flanges - 55-70 micro inches.

C. Design Quality Satisfactory.

D. Manufacturing Method & Quality Semi-permanent mold casting - Mold scribed - B.H.N. value indicates part in as-cast condition.

MICROSTRUCTURE: Medium aluminum - silicide constituent uniformly dispersed thru matrix.

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Part Name Oil Pan (Lower Crankcase)

Laboratory Serial No. 263163 Date

X-RAY EXAMINATION: XCED NO. H-160 Revealed a good sound structure, little to no shrink or porosity in this large casting - Good quality.

MACRO EXAMINATION: Photograph 6421, showed a medium to fine uniform grain structure, some pinhole porosity - Good quality casting.

CHEMICAL ANALYSIS: Si 8.7%, Cu Tr., Fe.1-1%, Mn .1-1%, Mg .1-1%, Ni /.5%, Zn /.5% Ti /.1%, Cr Nil, Zr Nil

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: B.H.N. 70 Weight of 54.0 Pounds

Finish Normal cleanup - slight core shift - Used phthalate type of coating on interior and exterior.

COMMENTS: A. Workmanship Some erosion - Some incomplete coring - rough finish possibly due to soft ramming.

B. Machining Finish machined flange faces to 100-110 micro inches. Machining allowances greater than needed.

C. Design Quality Satisfactory filleting and blending. Rib design poor-used a rounded rib design - Heavier section thickness in rib would be advisable.

D. Manufacturing Method & Quality Sand casting - Good quality - B.H.N. reveals part was in the as-cast condition.

MICROSTRUCTURE: Simple structure showing aluminum silicide dispersed thru matrix.

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6121 MACRO SECTION OF ENGINE OIL PAN

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Part Name Engine Crankcase (Upper)

Laboratory Serial No. 263164 Date

X-RAY EXAMINATION: XCED NO. H-161
Little to no shrink or porosity as normally detected by radiographic inspection - Good quality.

MACRO EXAMINATION: Macro inspection, photograph 6422, showed very large gross grain structure indicative of a slow cooling process during casting. Shrinkage evident in dendritic pattern.

CHEMICAL ANALYSIS: Si 10.7% Cu tr Fe .1-1% Mn .1-1% Mg .1-1%
Ni /.5% Zn /.5% Ti /.1% Cr Nil Zr Nil

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: BHN 93 Weight of 59 Pounds
Finish Poor cleanup on casting - Foreign inclusion in form of sand - some plate formed.
COMMENTS: A. Workmanship Satisfactory - Good sand coring practice. Slight washes.

B. Machining Satisfactory - Flanges machined to 100-169 micro inches. Sleeve insert surfaces ground to 25 to 30 micro inches.

C. Design Quality Satisfactory design - Good radii blending practiced. Boss areas slightly gross.

D. Manufacturing Method & Quality Semi-permanent mold casting - Good quality. BHN value indicates part was sol'n treated and aged to the Alcoa T_6 condition. Molds scribed to improve casting.

MICROSTRUCTURE: Silumin alloy - Aluminum silicide constituent dispersed thru aluminum matrix.

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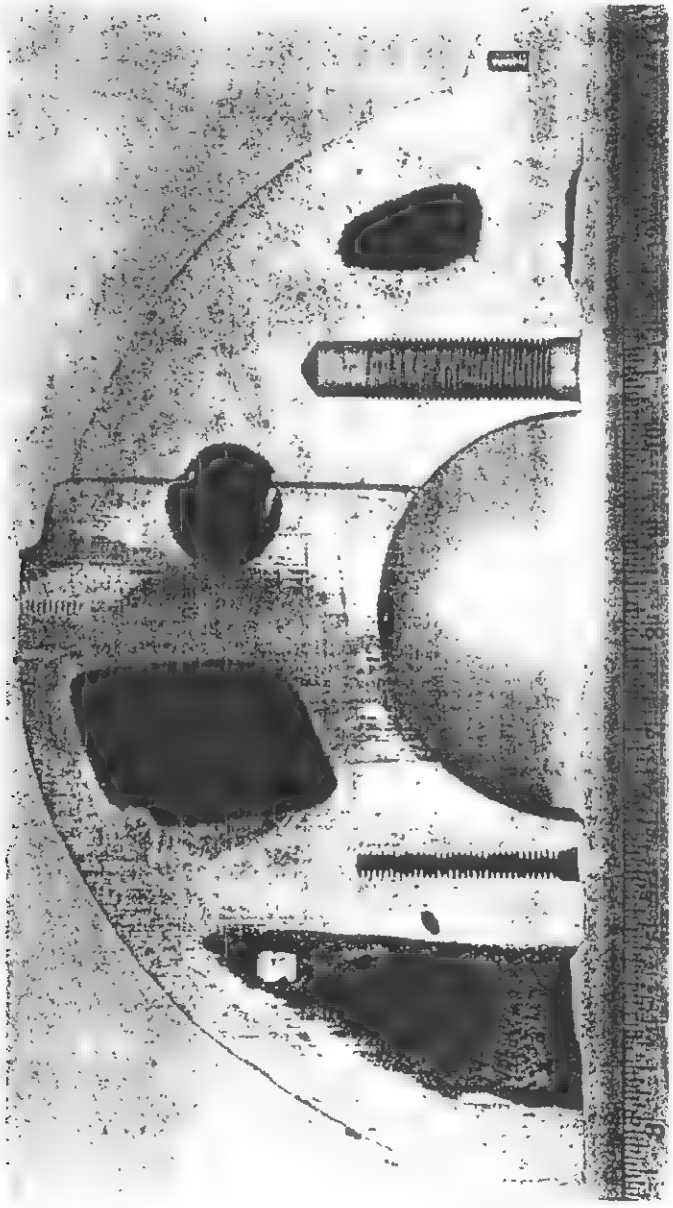

6422 - MACRO SECTION OF ENGINE CRANKCASE

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Part Name Engine Cylinder Block

Laboratory Serial No. 263165 Date

X-RAY EXAMINATION: XCED NO. H-162 Numerous blows in form of gas and porosity - One crack between #1 and #2 cylinders thru sound metal section - Good quality.

MACRO EXAMINATION: Macro inspection, photograph 6424, shows a fine uniform grain size - Metal quality good.

CHEMICAL ANALYSIS: Si 8.7%, Cu tr, Fe .1-1%, Mn .1-1%, Mg .1-1% Ni / .5%, Zn / .5%, Ti / .1%, Cr Nil, Zr Nil

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: BHN 93 Weight of 59 Pounds

Finish Poor cleanup on casting - Foreign inclusion in form of sand - Some plate formed.

COMMENTS: A. Workmanship Satisfactory - Good sand coring practice. Slight washes.

B. Machining Satisfactory - Flanges machined to 100-169 micro inches. Sleeve insert surfaces ground to 25 to 30 micro inches.

C. Design Quality Satisfactory design - Good radii blending practiced - Boss areas slightly gross.

D. Manufacturing Method & Quality Semi-permanent mold casting - Good quality. BHN value indicates part was sol'n treated and aged to Alcoa T6 condition. Molds scribed to improve casting.

MICROSTRUCTURE: Silumin alloy - aluminum silicide constituent dispersed thru aluminum matrix.

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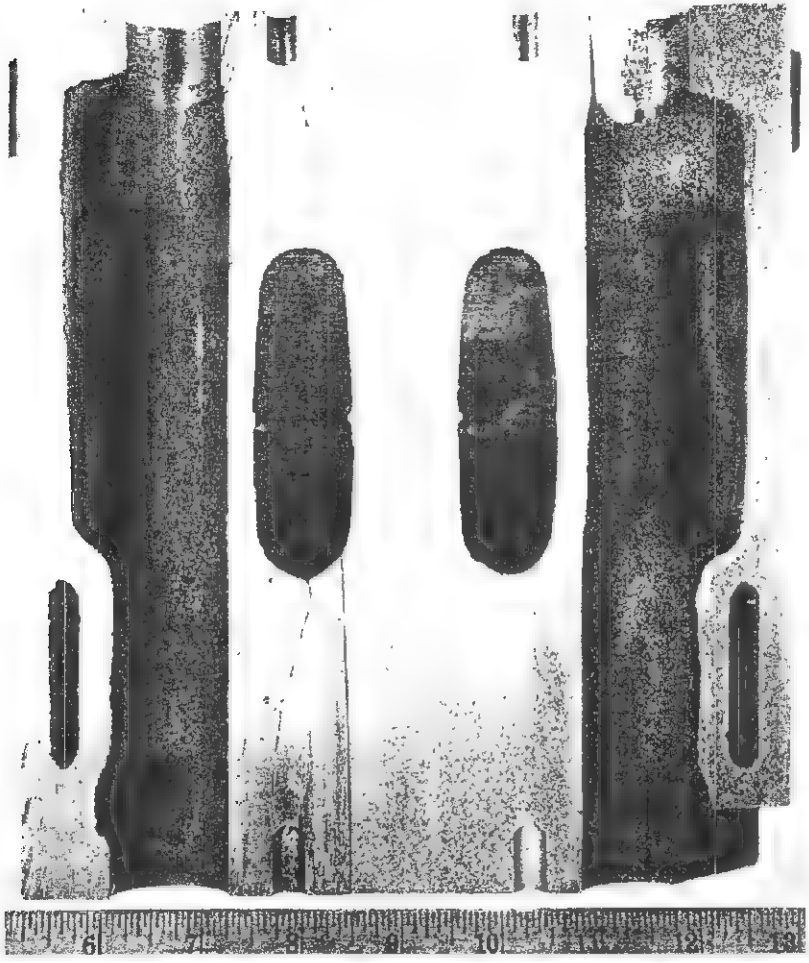

6424 - MACRO SECTION OF ENGINE CYLINDER BLOCK

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Part Name Engine Cylinder Head

Laboratory Serial No. 263166 Date

X-RAY EXAMINATION: XCED NO. H-163 Medium porosity noted in coolant passages - Core wire noted in coolant passages. Good quality.

MACRO EXAMINATION: Macro inspection, photograph 6423, showed uniform fine grain structure with some blows near sand cored areas in form of porosity and gas holes. Good quality of metal.

CHEMICAL ANALYSIS: Si 8.2%, Cu Tr Fe .1-1%, Mg .1-1%, Ni /.5%, Zn /.5%, Ti /.1%, Cr Nil, Zr Nil

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: 80 BHN Weight of 82.5 Pounds

Finish Cleanup did not appear to be excessive. Some inclusions in cored passages - Core wire.

COMMENTS: A. Workmanship Satisfactory. Rough interior surfaces possibly attributed to poor sand core handling or preparation.

B. Machining Satisfactory - Surfaces finished to 50-56 micro inches - Good machining allowances.

C. Design Quality Some tendency towards grossness in design - good filleting - blending practiced.

D. Manufacturing Method & Quality Semi-permanent mold casting - Good quality - BHN value indicates part had been stabilized for operating conditions to Alcoa T_6 condition.

MICROSTRUCTURE: Simple silumin structure containing aluminum-silicide constituent uniformly dispersed thru aluminum matrix.

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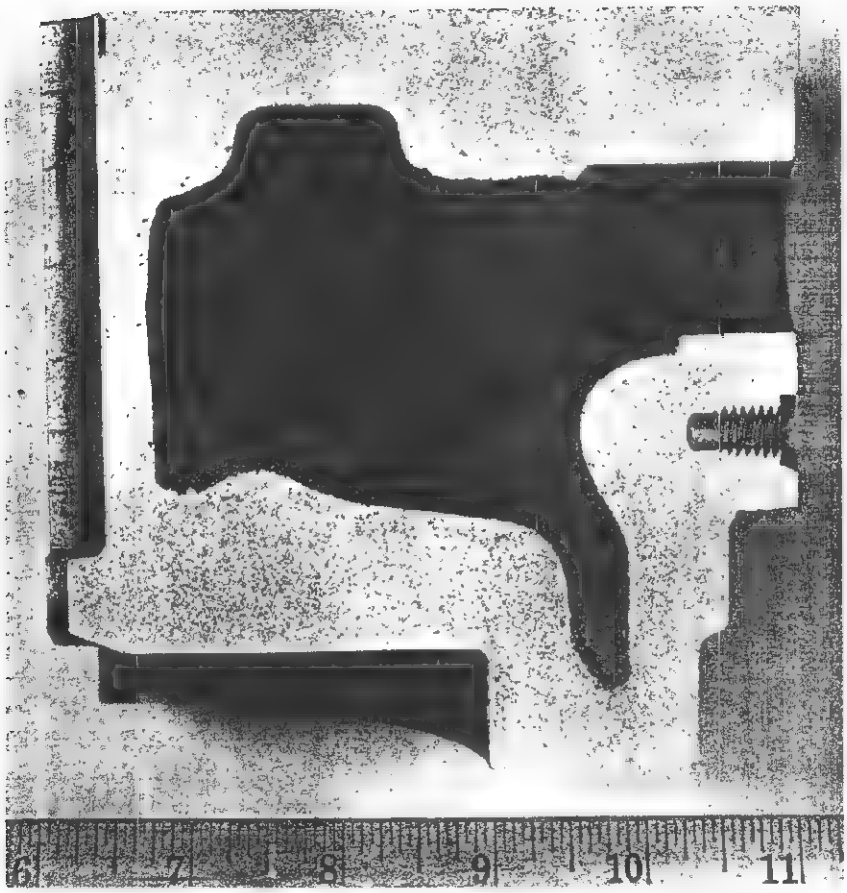

6423 - MACRO SECTION OF ENGINE CYLINDER HEAD

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Part Name Water Pump Impeller

Laboratory Serial No. 262981 Date

X-RAY EXAMINATION: XCED NO.

MACRO EXAMINATION: Inspection showed a uniform fine grain structure.

CHEMICAL ANALYSIS: Si 8.3%, Cr Tr, Fe .44%, Mg .26%, Mn .27%, Ti /.2%, Zn /.2%, Ni /.5%, Al Bal.

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: B.H.N. 86 Weight of 0.24 Pounds

Finish Rough finished casting - Used a gray marine type of paint to protect part from corrosion.

COMMENTS: A. Workmanship Satisfactory.

B. Machining Satisfactory - Normal amount of machining allowance maintained.

C. Design Quality Semi-permanent mold casting - Good quality. B.H.N. value indicates heat treatment to Alcoa T_6 condition. Mold scribed to promote sounder casting.

D. Manufacturing Method & Quality

MICROSTRUCTURE: Typical structure associated with silumin alloys - aluminum silicide dispersed uniformly in matrix.

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Part Name No. 1 Main Crankshaft Bearing Cap

Laboratory Serial No. _____ Date _____

X-RAY EXAMINATION: XCED NO. H-270 Revealed a casting of good quality - No noticeable porosity or shrinkage.

MACRO EXAMINATION: Inspection showed a uniform fine grain size - Quality of metal was good.

CHEMICAL ANALYSIS: Si 8.7%, Cu /1.0%, Fe .52%, Mg .11%, Mn .28%, Zn /.9%, Ni /.5%, Al Bal.

Compares to Alcoa 356 alloy [redacted] 25X1A

HARDNESS VALUE: B.H.N. 100 Weight of _____ Pounds

Finish Excessive cleanup - Tool marks noted.

COMMENTS: A. Workmanship Satisfactory - Exterior surfaces of mold very rough. Poor closing of the molds indicated.

B. Machining Machining allowances greater than required - Ground surfaces where bearings are attached.

C. Design Quality Other bearing caps were forged from 14S stock - Good blending - Satisfactory radii.

D. Manufacturing Method & Quality Permanent mold casting - Good quality - B.H.N. value indicates material was heat treated to Alcoa T6 condition.

MICROSTRUCTURE: Silumin alloy with simple structure of aluminum silicide dispersed thru matrix.

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Part Name Crankshaft Main Bearing Cap

Laboratory Serial No. 262055 Date

X-RAY EXAMINATION: XCED NO. H-024 No defects detected by radiographic inspection - Good quality.

MACRO EXAMINATION: Photograph 6369, showed forging was made from wrought blank with fibrous structure parallel to stresses.

CHEMICAL ANALYSIS: Cu 4.4%, Si 0.6%, Fe 0.39%, Mg 0.39%, Mn /1.0%, Cr /.1%, Ti /.1%, Zn /.3%, Ni /.5%

Compares to Alcoa 14ST alloy [redacted] 25X1A

HARDNESS VALUE: B.H.N. 105 Weight of 4.22 Pounds

Finish Rough surface - Excessive flash of 5/16" at parting line. Tong not trimmed - poor cleanup.

COMMENTS: A. Workmanship Satisfactory - Material could have been worked more for bulk or size of blank used.

B. Machining Ground finish in areas where bearing fits to cap 40-50 micro inches. Rough bored bolt holes.

C. Design Quality Satisfactory - Simple filleting in critically stressed areas. Wall thickness in upper portion is very thin.

D. Manufacturing Method & Quality Forging - Satisfactory - B.H.N. values indicate a poor or improper heat treatment.

MICROSTRUCTURE: Stringer type of structure with Copper-Aluminum and Aluminum - Copper - Manganese - Iron constituent in matrix. No evidence of high temperature oxidation.

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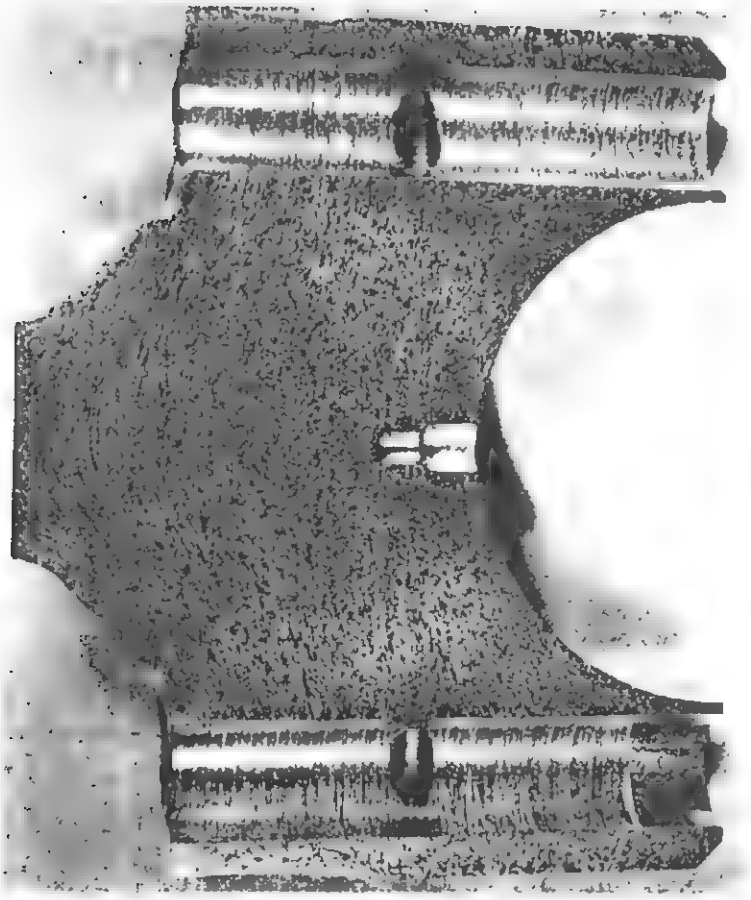

6369 - MACRO SECTION OF MAIN BEARING CAP

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Part Name Engine Piston

Laboratory Serial No. 262087 Date

X-RAY EXAMINATION: XCED NO. H-092 No defects noted during radiographic inspection. Very sound dense structure - Good quality.

MACRO EXAMINATION: Dy-Check showed forging seam which formed seam extending 1/2" into piston head. Macro, photographs 6384A-B, lack of uniform metal flow in forged part. Quality fair.

CHEMICAL ANALYSIS: Fe 1.50%, Cu 2.6%, Ni 2.7%, Mg 2.2%, Mn .17%, Zn Nil, Si .87%, Al Bal.

Compares to

HARDNESS VALUE: See attached sheet Weight of 5.26 Pounds

Finish No electro plated or chemical finishes. Machining allowances satisfactory.

COMMENTS: A. Workmanship Wall section on one side where balancing was performed showed 1/2" reduction in wall thickness over opposite side.

B. Machining Machined and ground surfaces on piston skirt 120 micro inches; pin hole 50-55 micro inches; polished head 30 micro inches.

C. Design Quality Truck type piston - Not cam ground - Adequate oil return holes - Heavy crown head - Good fillets. Back of head reinforced with ribs for conductivity and strength.

D. Manufacturing Method & Quality Forging - Satisfactory or fair quality. B.H.N. indicates Alcoa T6 condition - Solution heat treat and aged. Engine temperatures reduced hardness in crown of piston as shown in accompanying sketch.

MICROSTRUCTURE: Copper - aluminum - iron constituent at grain boundaries near coarse nickel - aluminum constituent uniformly dispersed thru forged structure. High nickel gives hot strength to alloy.

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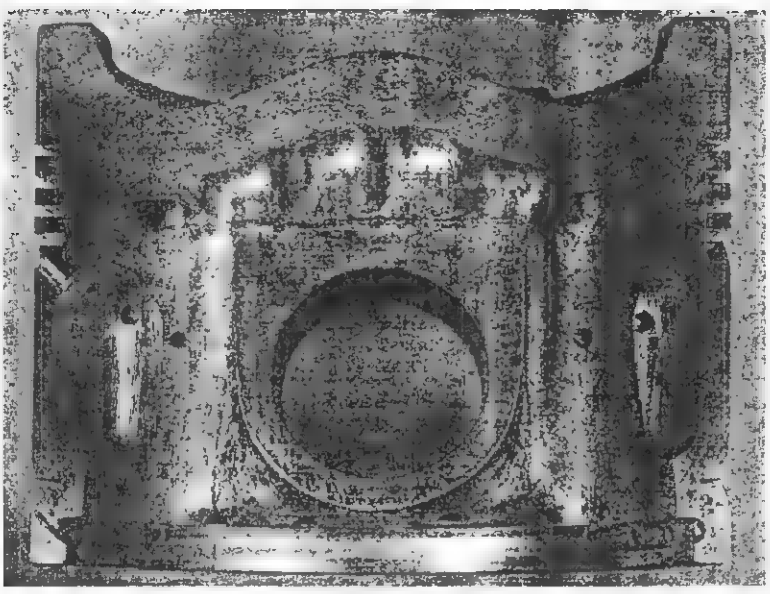

6384 A - MACRO SECTION OF PISTON

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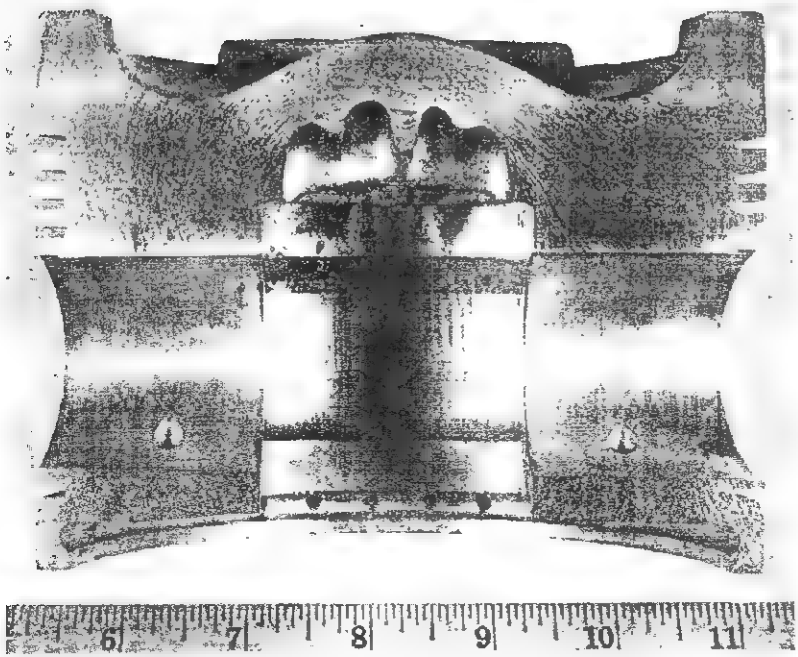

6384 B - MACRO SECTION OF PISTON

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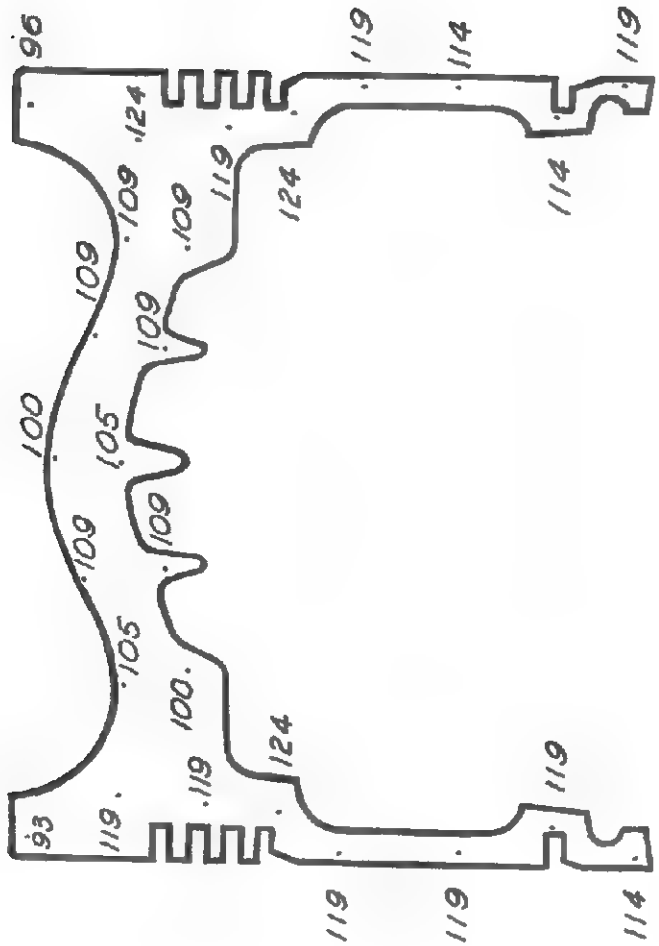

0104.1 - BRINELL HARDNESSES OF PISTON CROSS SECTION

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Part Name Air Cleaner to Intake Manifold Elbow

Laboratory Serial No. 263237 Date

X-RAY EXAMINATION: XCED NO. E-170 Heavy blows throughout casting in form of gas holes and medium to heavy porosity. Cracks radiating from chaplets - poor quality.

MACRO EXAMINATION: Photograph 6417, showed uniform fine grain structure with pin hole porosity thru structure - oxide inclusions - poor quality.

CHEMICAL ANALYSIS: Si 2.3%, Cu 7.4%, Fe .1-1%, Mn Nil, Mg/.1%, Ni /.5%, Zn 2.0%, Ti /.1%, Cr Nil, Zr Nil

Compares to Alcoa 113 alloy

HARDNESS VALUE: B.H.N. 77 Weight of 10.30 Pounds

Finish Poor cleanup - Rough exterior and interior - core shift washes - sand inclusions - tool marks.

COMMENTS: A. Workmanship Soft ramming of sand noted - quality control on sand seemingly poor.

B. Machining Satisfactory - although machining allowances apparently more than required.

C. Design Quality Grossness in design - poor blending of wall sections. Chaplets caused severe segregation causing cracks.

D. Manufacturing Method & Quality Sand casting - Poor quality. B.H.N. values indicate as-cast condition.

MICROSTRUCTURE: Aluminum copper and acicular aluminum silicide uniformly dispersed in matrix.

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6417 - MACRO SECTION OF AIR CLEANER-TO-INTAKE MANIFOLD ELBOW

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Part Name Gun Safety Switch Box

Laboratory Serial No. 263837 Date

X-RAY EXAMINATION: XCED NO. H-250 Revealed a sound casting free of defects normally detected by radiographic inspection. Good quality.

MACRO EXAMINATION: Photograph 6443, showed fine to medium grain structure. Good metal quality.

CHEMICAL ANALYSIS: Cu 5.7%, Si 1.6%, Fe 1.3%, Mn .53%, Mg .20%, Ni /.20%, Zn /.50%, Al Bal

Compares to Alcoa 195 alloy.

HARDNESS VALUE: B.H.N. 105 Weight of 1.10 Pounds

Finish Normal cleanup - Painted green (dark)

COMMENTS: A. Workmanship Satisfactory - No defects noted.

B. Machining Satisfactory - Hole deformed during drilling operations. Too much reduction in wall section in several holes.

C. Design Quality Good attention to fillets - wall section too thin in some areas.

D. Manufacturing Method & Quality Permanent mold castings - Good quality. B.H.N. value indicates part was heat treated to Alcoa T_6 condition (Sol'n Treat and age)

MICROSTRUCTURE: Copper - Aluminum and Cu-Fe-Mn-Al constituents - Plus a brittle phase in which numerous fine cracks were noted and oxide inclusions.

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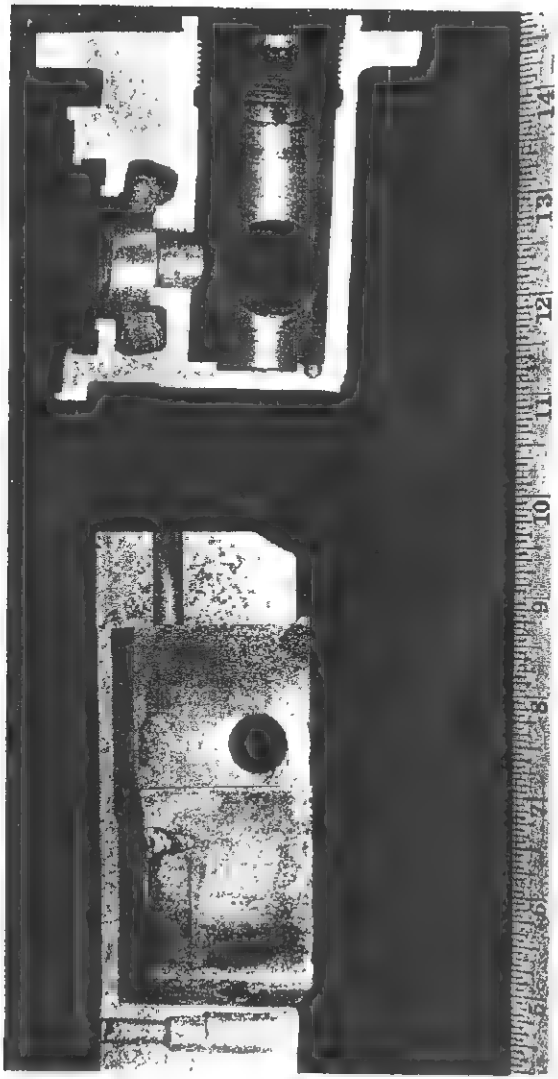

6443 - MACRO SECTIONS OF T34 COMPONENTS

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Part Name Fuel Transfer Pump Body

Laboratory Serial No. 263835 Date

X-RAY EXAMINATION: XCED NO. H-251 Revealed some micro shrinkage radiating from hole, also some porosity (slight) in body section - Good quality.

MACRO EXAMINATION: Photograph 643, shows a uniform medium grain size to fine grain size. Very good metal quality.

CHEMICAL ANALYSIS: Cu 2.15%, Si 4.9%, Fe .65%, Mn .50%, Mg /.10%, Ni /.20%, Zn /.50%, Al Bal.

Compares to Alcoa 195 alloy

HARDNESS VALUE: B.H.N. 76 Weight of 1.10 Pounds

Finish Normal cleanup - No tool marks - Very good condition - Suspect chromate chemical treatment used as a protective coating on interior and exterior of part.

COMMENTS: A. Workmanship Good workmanship - Good coring of internal passages. Good cleanup - No inclusions.

B. Machining Good machine - satisfactory machining allowances practiced - pump portion ground finish.

C. Design Quality Satisfactory - good blending - good fillets - good wall section and thickness design.

D. Manufacturing Method & Quality Sand casting - Good quality - B.H.N. value indicative of part being in as-cast condition.

MICROSTRUCTURE: Simple structure of fine acicular Al-Si uniformly dispersed in matrix with some Cu-Al phase.

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Part Name Water Filler and Pressure Cap Housing

Laboratory Serial No. 263765 Date

X-RAY EXAMINATION: XCED NO. H-241 Revealed heavy blows i.e., excessive porosity and gas holes - Poor quality.

MACRO EXAMINATION: Photograph 6433, showed a uniform grain structure. Heavy corrosion noted at inlet and outlet ports of "T" fitting - Metal quality appeared good.

CHEMICAL ANALYSIS: Cu 8.2%, Si 0.83%, Zn 25.4%, Mn /.1%, Fe 1.15%, Mn .25%, Ni /.5%, Al Bal.

Compares to High zinc alloys which are seldom used even in present European practice.

HARDNESS VALUE: B.H.N. 100 Weight of 1.12 Pounds

Finish Satisfactory - Normal cleanup - Some burned sand as inclusions.

COMMENTS: A. Workmanship Satisfactory - Only slight evidence of washes or erosion in interior passages.

B. Machining Satisfactory - Good tapped threads - Normal machining allowances.

C. Design Quality Satisfactory - Fillets good - blending good - wall sections adequate - no grossness in design.

D. Manufacturing Method & Quality Sand casting - Poor choice of alloy for part - B.H.N. value indicates hardness due possibly to natural aging of part. Ordinary heat treat outside of low temp. aging could cause hot shortness.

MICROSTRUCTURE: Heavy intergranular attack thru Cu-Al and some unidentified constituent in form of Chinese script. This appears to have been a poor application for this high zinc alloy.

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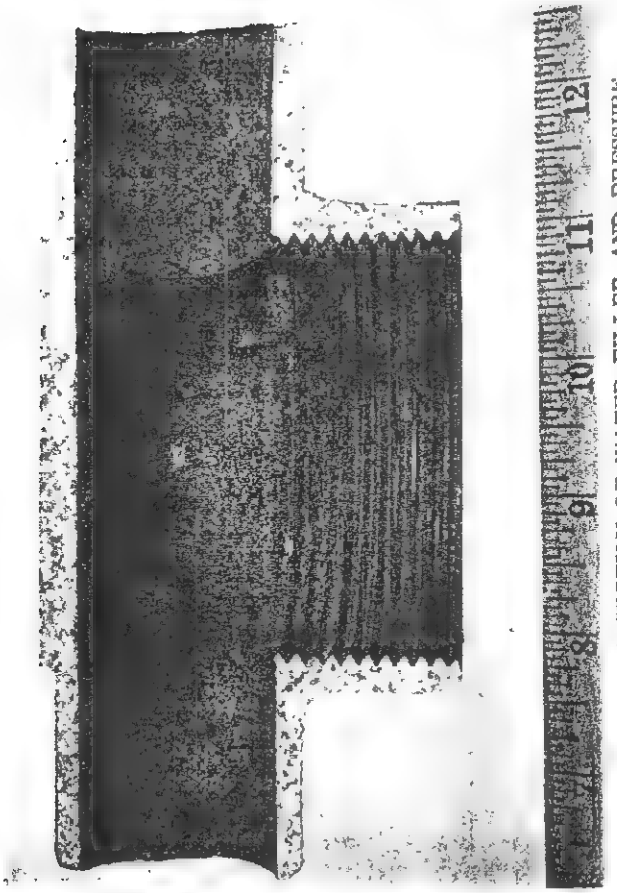

6433 - MACRO SECTION OF WATER FILLER AND PRESSURE CAP HOUSING

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Part Name Fuel Transfer Pump Drive Shaft Body Seal

Laboratory Serial No. 263833 Date

X-RAY EXAMINATION: XCED NO. Omitted

MACRO EXAMINATION: Photograph 6442, revealed a uniform fine grain size. Quality of metal was good. (See page 355 for photo).

CHEMICAL ANALYSIS: Cu 4.2%, Fe .38%, Mn .42%, Mg .41%, Ni /.2%, Zn /.50%

Compares to Alcoa 178 alloy

HARDNESS VALUE: B.H.N. 99 Weight of 0.075 Pounds

Finish Used anodic coating. Color suggests chromate method. Thickness was approx. .0002".

COMMENTS: A. Workmanship Satisfactory. No defects noted which could be attributed to faulty workmanship.

B. Machining Satisfactory - Standard and good machine practices observed.

C. Design Quality Satisfactory - Good attention given to section thickness and radii.

D. Manufacturing Method & Quality Wrought bar stock used probably in a screw machine. Good quality - B.H.N. value indicates material was in Alcoa T_4 condition (Sol'n and heat treat)

MICROSTRUCTURE: Fine uniformly dispersed copper aluminum constituent. Normal wrought structure. No inclusions detected.

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Part Name Cylinder Head Gasket

Laboratory Serial No. 262054 Date

X-RAY EXAMINATION: XCED NO. Omitted

MACRO EXAMINATION: If aluminum gasket is to be used, 2S is a good selection or choice. However, it should be in a softer condition than B.H.N. 44.

CHEMICAL ANALYSIS: Si /.1%, Cu /.1%, Fe 0.16%, Mg /.1%, Cr /.1%, Mn /.1%, Ti /.1%, Zn /.5%, Ni /.5%,

Compares to Alcoa 2S alloy [redacted] 25X1A

HARDNESS VALUE: B.H.N. 44 Weight of 1.30 Pounds

Finish Satisfactory - Part fabricated from sheet stock of uniform thickness.

COMMENTS: A. Workmanship Satisfactory - No tool marks or other defects indicative of faulty workmanship.

B. Machining Finish surface of 50 micro inches. Raised lands around each cylinder to obtain suitable seal.

C. Design Quality Satisfactory - Ample use of expansion slots between cylinders.

D. Manufacturing Method & Quality Stamping - Good quality - B.H.N. value indicates material was cold worked to the Alcoa herd condition.

MICROSTRUCTURE: Excessive number of rosettes indicative of eutectic melting and ordinarily not present in an alloy of this composition. However, their presence shows that excessive temperatures were incurred during some fabrication process.

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Part Name Tachometer Mounting Bracket

Laboratory Serial No. 263838 Date

X-RAY EXAMINATION: XCED NO. H-249 Revealed blows in form of gas holes - also, some shrink and fine cracks. Quality of casting fair.

MACRO EXAMINATION: Photograph 6442 showed a very dense fine grain size. Quality of material was good. (See page 355 for photo).

CHEMICAL ANALYSIS: Si 4.8%, Cu 3.8%, Fe .82%, Mn .38%, Mg .44% Ni /.20%, Zn .62%, Al Bal.

Compares to Alcoa 85 - Die casting alloy

HARDNESS VALUE: Weight of 0.10 Pounds

Finish Excessive cleanup leaving numerous tool marks, near parting lines

COMMENTS: A. Workmanship Satisfactory - However, dies used to cast part were leaving excessive amount of flash.

B. Machining Little machining necessary on this part. Surfaces very good in as-cast condition.

C. Design Quality Satisfactory - However, better rib design and filleting could have been practiced.

D. Manufacturing Method & Quality Die casting - Good quality - no hardness values taken on die casting.

MICROSTRUCTURE: Simple structure composed of very fine Cu-Al-Si constituent at grain boundaries - Some porosity noted.

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Part Name Lower Transmission Case

Laboratory Serial No. 263162 Date

X-RAY EXAMINATION: XCED NO. H-159
Revealed scattered porosity, however, quality of casting considered good.

MACRO EXAMINATION: Macro inspection revealed a uniform fine grain size of dense structure having a good metal quality.

CHEMICAL ANALYSIS: Si tr, Cu 2.7%, Fe tr, Mg /.1%, Mn Nil, Zn 13.5%, Al Bal

Compares to Alcoa 645 alloy (Approx.)

HARDNESS VALUE: BHN 86 Weight of 115 Pounds

Finish Poor cleanup noted at riser and gates in form of toolmarks - also foreign inclusions.

COMMENTS: A. Workmanship Satisfactory workmanship in vital areas - Some evidence of soft ramming in sand mold.

B. Machining Surfaces used as bearing areas had ground surfaces of 53-58 micro inches.

C. Design Quality Good blending of sections - ample fillets - Grossness in wall thickness noted.

D. Manufacturing Method & Quality Sand Casting - Good Quality - As cast condition - Heat Treatment with high zinc content would result in hot shortness in part.

MICROSTRUCTURE: Simple structure showing $CuAl_2$ constituent - Zinc is in solid solution and not visible.

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Part Name Upper Transmission Case

Laboratory Serial No. 263162 Date

X-RAY EXAMINATION: XCED NO. H-159 Scattered porosity and some gas holes noted in casting. Porosity near junction of heavy to thin sections - Good quality.

MACRO EXAMINATION: Macro inspection, photograph 6420, showed a uniform fine grain structure. Good metal quality.

CHEMICAL ANALYSIS: Cu 3.5%, Zn 13.3%, Si tr, Fe tr, Mg /.1%, Mn Nil, Al Bal.

Compares to Alcoa 645 alloy

HARDNESS VALUE: BHN 74 Weight of 118.5 Pounds

Finish Poor cleanup - Gates knocked off with hammer. Tool marks noted - some sand inclusions.

COMMENTS: A. Workmanship Fair to good in vital areas - part showed some evidence of poor sand molding.

B. Machining Ground finish to 40-50 micro inches in bearing areas. Adequate machining allowances.

C. Design Quality Satisfactory - Good blending - filleting - Grossness in wall thickness and bosses noted.

D. Manufacturing Method & Quality Sand Casting - Good quality. As-cast condition - Heat treatment of this high zinc alloy would result in hot shortness.

MICROSTRUCTURE: Simple structure showing Copper-Aluminum constituent at grain boundaries - Zinc is in solid solution and not visible.

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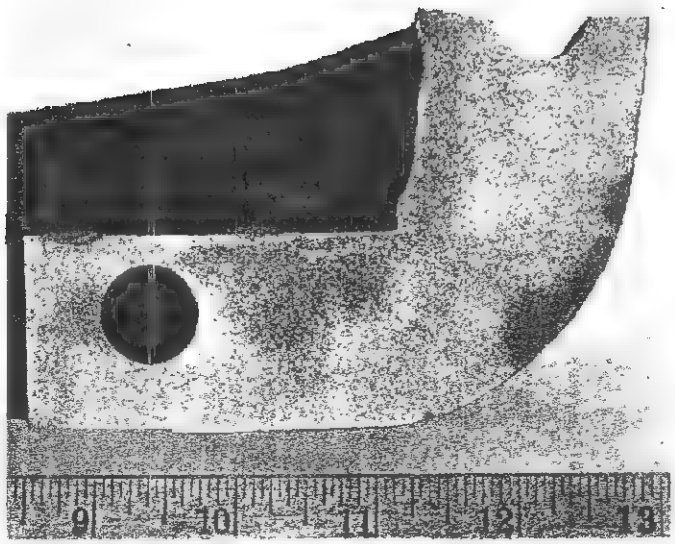

6420 - MACRO SECTION OF TRANSMISSION CASE

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Part Name Piston Pin Plug

Laboratory Serial No. 262087 Date

X-RAY EXAMINATION: XCED NO. Omitted

MACRO EXAMINATION: Macro inspection showed a uniform grain size - Quality of metal was good.

CHEMICAL ANALYSIS: Si 1.15%, Cu 5.80%, Fe 1.08%, Mg .48%, Mn .63%, Ni Nil, Zn Nil, Al Bal

Compares to Alcoa 14S alloy [redacted] 25X1A

HARDNESS VALUE: B.H.N. 99 Weight of 0.08 Pounds

Finish No chemical or electroplated finish noted by spectrographic analysis.

COMMENTS: A. Workmanship Satisfactory - No defects noted which could be attributed to faulty workmanship.

B. Machining Rough machining in non-vital areas. Ground finish to 35-40 micro inches on bushing areas.

C. Design Quality Satisfactory.

D. Manufacturing Method & Quality Wrought bar stock - Probably used in a screw machine setup - B.H.N. value indicates parts are in the Alcoa T_4 condition.

MICROSTRUCTURE: Typical elongated structure of 14S alloy showing Cu Al_2 and some constituent tentatively identified as Mg-silicide.

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SECTION B - ZINC ALLOYS

Zinc base alloys used in the T34 tank were cast as sand, permanent mold, and die castings. In composition these alloys compared to the Zamak 2, 3, and 5 alloys used in the United States.

Whenever zinc alloys are examined for quality particular attention is devoted to the quantity of contaminating elements lead, tin, and cadmium present in the alloy. The care taken to control these elements to low maximum limits is a good indication of the extent to which foundry control is practiced by the manufacturer. If the contaminating elements are not controlled heavy intergranular corrosion will occur in the form of heavy products between the grains, resulting in a failure of the part.

In the T34 tank parts these limits were maintained slightly above the maximum recommended in our practice - see Table I. As a result two die cast parts, i.e. periscope body and odometer-speedometer assembly showed the effects of intergranular attack upon micro examination and inspection of the fractured pieces. In the fractured parts intergranular attack appeared as a uniform dark band which had progressed inwards to a depth of 0.020".

Group I

Zinc-Aluminum-Copper Alloys

Chemical composition ranges between limits:

Copper	2.5-3.5%
Aluminum	3.5-4.5%
Lead	Max. .007%
Cadmium	Max. .005%
Tin	Max. .005%
Zinc	Balance

Chemical analysis given in Table I indicates that the periscope body was die cast from an alloy comparable to Zamak 2. It is used where high strength and hardness are necessary. Our analysis indicated that some control was exercised to avoid excessive amounts of cadmium, tin, and lead in the die castings.

Group II

Zinc-Aluminum Alloys

Chemical composition ranges between limits:

Copper	Max. .10%
Aluminum	3.5-4.5%
Magnesium	.03-.08%
Iron	Max. .10%
Lead	Max. .007%
Cadmium	Max. .005%
Tin	Max. .005%
Zinc	Balance

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The speedometer-odometer body employed an alloy comparable to Zamak 3. It is a general purpose alloy in which a greater dimensional stability can be maintained than with the other zinc alloys. Also, alloys in this grouping have better physical properties at elevated temperatures. Because of these characteristics the castings can be stabilized prior to service installations.

Group III

Zinc-Aluminum Alloy

Chemical composition ranges between limits:

Copper	0.75-1.25%
Aluminum	3.5-4.30%
Magnesium	0.03-0.08%
Iron	0.1000%
Lead	Max. .007%
Cadmium	Max. .005%
Tin	Max. .006%
Zinc	Balance

An alloy from this group was used in fabrication of the fuel tank selector valve body. The alloy was comparable to Zamak 5 which is a general purpose alloy having good dimensional stability and impact strength at room temperature. At elevated temperatures, however, it was subject to growth and loss of impact strength.

The remainder of section B describes the examination conducted on each of zinc base parts.

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Part Name Periscope Body

Laboratory Serial No. 263780 Date

X-RAY EXAMINATION: XCED NO. H-242 Revealed excessive amount of gas holes and porosity in castings - Poor quality.

MACRO EXAMINATION: Macro inspection showed a heavy centerline porous condition through body of part.

CHEMICAL ANALYSIS: Cu 2.7%, Al 3.0%, Fe /.05%, Mg /.02%, Pb .008% Sn /.005%, Cd .007%, Zn Bal

Compares to Zamak 2 alloy [redacted] 25X1A

HARDNESS VALUE: Weight of 4.09 Pounds

Finish Heavy cleanup on riser and gate areas. No chemical or other protective treatments detected on this part.

COMMENTS: A. Workmanship Saw cuts and other tool marks noted on casting. Excessive flash indicative of molds not closing properly - Poor mold work.

B. Machining Satisfactory. Normal machining allowances observed on part.

C. Design Quality Poor design - excessive grossness in wall sections.

D. Manufacturing Method & Quality Die Casting - Poor quality. As-cast condition.

MICROSTRUCTURE: Structure - large white particles of primary solid solution of copper and aluminum in zinc - in matrix of eutectic formed by zinc rich and aluminum rich primary solid solution phases.

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Part Name Speedometer, Odometer Body

Laboratory Serial No. 263836 Date

X-RAY EXAMINATION: XCED NO. H-248 Revealed gas porosity throughout body, however, it was not excessive - consider casting to be of fair quality.

MACRO EXAMINATION: Macro inspection, photograph 6442, showed porosity in center portion of a heavy section. Metal quality good.

CHEMICAL ANALYSIS: Cu Tr, Fe /.05%, Mg .10%, Pb .013%, Sn /.005%, Cd .007%, Al 4.8%, Zn Bal

Compares to Zamak 3 [redacted] 25X1A

HARDNESS VALUE: Weight of 0.30 Pounds

Finish Satisfactory - no excessive cleanup - no chemical or electroplated coatings used.

COMMENTS: A. Workmanship Satisfactory - Good mold work - Good coring.

B. Machining Satisfactory - Confined to finish cuts and tapping - holes being cored - no drilling required.

C. Design Quality Good design with proper section thickness used - Good draft and coring practiced.

D. Manufacturing Method & Quality Zinc Die Casting - Good quality - as-cast condition - no heat treatment.

MICROSTRUCTURE: Typical structure - shows eutectic structure formed zinc rich and aluminum rich primary solid solution phases.

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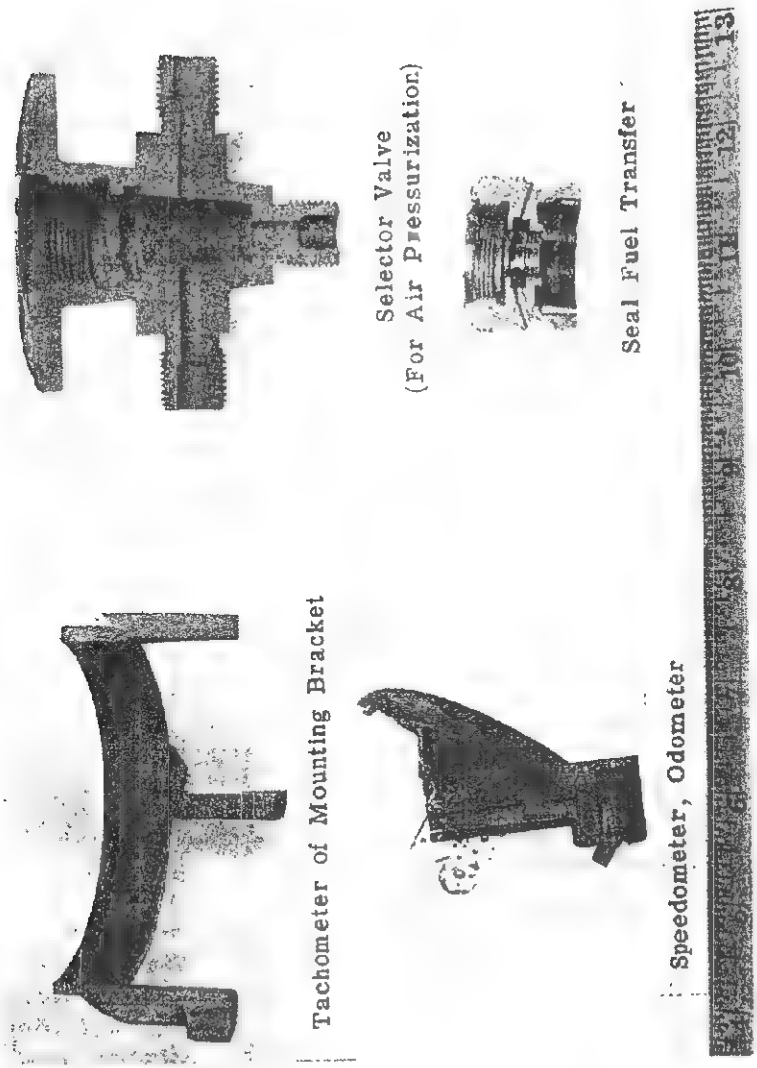

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Part Name Fuel Tank Selector Valve (For Air Pressurization)

Laboratory Serial No. 263839 Date

X-RAY EXAMINATION: XCED NO. H-257 Revealed a sound casting of very good quality.

MACRO EXAMINATION: Macro inspection, photograph 6442, showed a very fine uniform grain structure - Quality of metal good.

CHEMICAL ANALYSIS: Al 4.7%, Cu 1.4%, Fe /.05%, Mg /.02%, Pb .007%, Sn /.005%, Cd .008%, Zn Bal

Compares to Zamak 5 [redacted] 25X1A

HARDNESS VALUE: Weight of .88 Pounds

Finish Satisfactory - normal cleanup - no chemical or electroplated coatings used on part.

COMMENTS: A. Workmanship Satisfactory - Mold operation evidently good.

B. Machining Normal machining allowances used - all external threads were well cut.

C. Design Quality Good design - Satisfactory blending of sections with ample radii.

D. Manufacturing Method & Quality Permanent Mold Casting - Good quality - no heat treatment - as-cast condition.

MICROSTRUCTURE: Structure has large white particles of primary solid solution of copper and aluminum in zinc- in matrix of eutectic formed by zinc rich and aluminum rich solid solution phases.

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Part Name Fuel Tank Selector Valve Body

Laboratory Serial No. 263781 Date

X-RAY EXAMINATION: XCED NO. H-243 Revealed a highly porous casting - Quality of casting considered poor.

MACRO EXAMINATION: Macro inspection, photograph 6432, showed a uniform fine grain size. Metal quality good.

CHEMICAL ANALYSIS: Cu 1.4%, Al 4.2%, Fe /.05%, Mg /.02%, Pb .008%, Sn /.005%, Cd .007%, Zn Bal

Compares to Zamak 5 alloy [redacted] 25X1A

HARDNESS VALUE: Weight of 0.30 Pounds

Finish Very rough surface on casting - no chemical or electroplated coatings used on part.

COMMENTS: A. Workmanship Quality of sand mold was poor - showed effects of soft ramming.

B. Machining Satisfactory, however, excessive machining allowances were used.

C. Design Quality Satisfactory - proper blending radii used. Section thickness adequate.

D. Manufacturing Method & Quality Sand Casting - Fair quality - as-cast condition. Normally sand castings from this alloy are confined solely to experimental work.

MICROSTRUCTURE: Structure - white particles of solid solution of copper and aluminum in zinc - in matrix of eutectic formed by zinc rich and aluminum rich solid solution phases.

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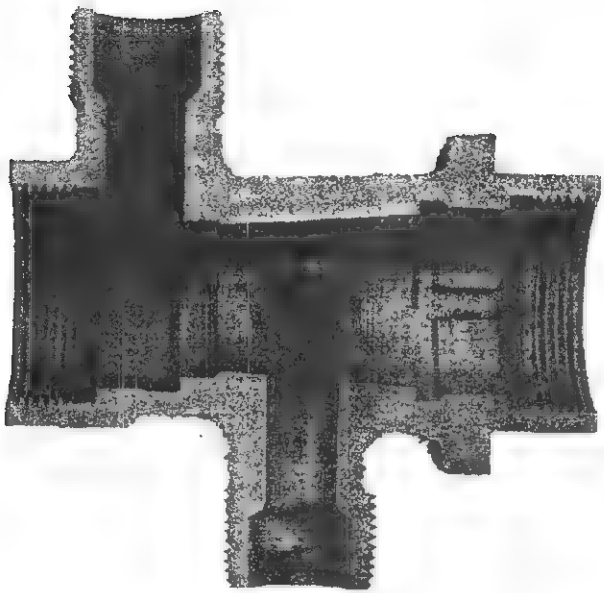

6432 - MACRO SECTION OF FUEL TANK SELECTOR VALVE BODY

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SECTION C - COPPER ALLOYS

Copper alloys although limited with respect to weight were used in a number of electrical and cooling system applications in the T34 tank. These materials are comparable to alloys used in other countries for sheet, bar and cast products. All copper-containing components were not investigated, however, various parts as listed in Table I thought to be of a representative nature were studied.

The role of non-ferrous alloys in bearing fabrication is brought out later in this report.

Group I

Copper-Zinc Alloys

Chemical composition ranges between limits:

Copper	59% to 62%
Zinc	Balance

Brasses in the above range are known as Muntz metal. These alloys have high strength combined with low ductility. Their application in the tank engine was limited to small parts such as washers and valve stems. Also, these alloys have excellent hot working qualities but only a fair degree of cold workability. Their machinability characteristics are good.

Group II

Copper-Zinc-Tin Alloy

Chemical composition ranges between limits:

Copper	94% to 96%
Tin	1% to 3%
Zinc	Balance

Alloys in this group are applicable to parts such as the starter switch contact assembly in which good electrical conductivity and spring qualities are required. This alloy has good corrosion properties, resistance to dissipation in heat of arcing, and resistance to mechanical wear. It is well to note, however, that in this part the aforementioned properties were not depended upon. Instead silver attached to above bronze clip was used as a contact point.

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Group III

Copper-Aluminum-Iron Alloys

Chemical composition ranges between limits:

Aluminum	8.5-9.5%
Iron	2.5-4.0%
Copper	Balance

The outer portion of the turret drive worm wheel was made from an aluminum bronze alloy of this composition. It is a non-heat treatable type of aluminum bronze suitable for severe service. These alloys have excellent wear resistant and anti-friction properties needed for this application.

Group IV

Copper-Silicon-Zinc Alloys

Chemical composition ranges between limits:

Copper	80.0 to 83.0%
Silicon	3.0 to 4.25%
Zinc	Balance

Although composition of the periscope plate (see Table I) does not fall within the range given above, enough similarity exists to class it as a silicon brass. As such it compares to the ASTM B-176-50T, alloy C type. This alloy is generally reserved for pressure die castings, however, in the fabrication of the periscope plate the sand casting method was employed. Alloys of this group have good fluidity, high tensile properties and are well adapted to intricate shapes.

The remainder of this section contains a detailed account of the inspection of each of the copper parts.

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Part Name Periscope Plate

Laboratory Serial No. 263782 Date

X-RAY EXAMINATION: XCED NO. H-244 Revealed heavy porosity in large area of casting - Quality of casting poor.

MACRO EXAMINATION: Macro inspection, photograph 6441, showed a medium grain size with foreign inclusions. Metal quality good.

CHEMICAL ANALYSIS: Cu 79.5%, Si 2.5%, Zn Bal

Compares to Silicon Brass ASTM

HARDNESS VALUE: Rockwell "B" 63 Weight of 1.62 Pounds

Finish Excessive cleanup required - Foreign inclusions noted in casting - rough surfaces.

COMMENTS: A. Workmanship Quality of sand was poor, as evidenced by numerous sand inclusions through part.

B. Machining Excessive machining allowances used. Quality of machining and tapped holes was good.

C. Design Quality Grossness in design noted.

D. Manufacturing Method & Quality Sand Casting - Quality fair.

MICROSTRUCTURE: Simple alpha brass structure with fine inclusions (foreign) noted in part.

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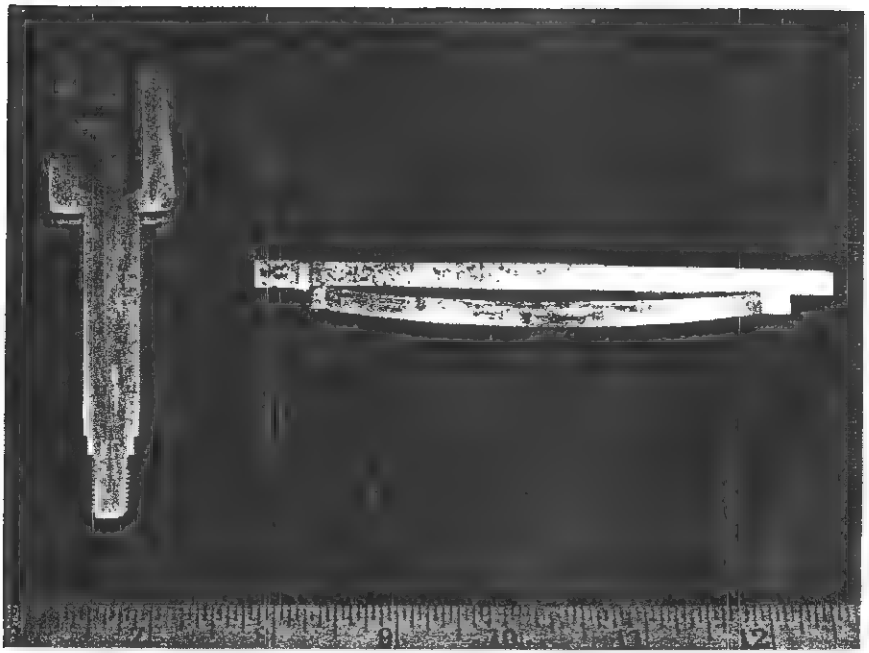

Selector Valve Periscope Plate

6441 - MACRO SECTION OF T34 COMPONENTS

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Part Name Fuel Tank Selector Valve

Laboratory Serial No. 263781 Date

X-RAY EXAMINATION: XCED NO.

MACRO EXAMINATION: Macro inspection, photograph 6441, showed a coarse elongated grain structure in center of part.

CHEMICAL ANALYSIS: Cu 58.3%, PB .20%, Zn Bal

Compares to Muntz Metal

HARDNESS VALUE: Rockwell "B" 63 Weight of 0.40 Pounds

Finish Heavy hammer marks noted on valve stem.

COMMENTS: A. Workmanship No comments

B. Machining Rough machining on non vital areas - Finish machined on valve surfaces.

C. Design Quality Satisfactory

D. Manufacturing Method & Quality Wrought bar stock - Machined - Fair quality.

MICROSTRUCTURE: Typical beta brass structure - No inclusions noted.

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Part Name Main Bearing Thrust Rod Washer

Laboratory Serial No. 262053 Date

X-RAY EXAMINATION: XCED NO.

MACRO EXAMINATION:

CHEMICAL ANALYSIS: Cu 61.6%, Sn Nil, Pb Nil Fe tr, Ni tr, Zn Bal

Compares to Muntz Metal

HARDNESS VALUE: Rockwell "B" 47 Weight of .05 Pounds

Finish No comments

COMMENTS: A. Workmanship Effects of rough stamping noted at O.D. and I.D. of washer.

B. Machining None

C. Design Quality No comments

D. Manufacturing Method & Quality Stamping - Fair quality - Stock cold worked to hard condition.

MICROSTRUCTURE: Typical Beta brass structure showing effects of cold work at I.D. and O.D.

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Part Name Connecting Rod Pin Washer

Laboratory Serial No. 262265 Date

X-RAY EXAMINATION: XCED NO.

MACRO EXAMINATION:

CHEMICAL ANALYSIS: Cu 62.0%, Sn Nil, Pb Nil, Fe Tr, Ni Tr, Zn Bal

Compares to Muntz Metal

HARDNESS VALUE: Rockwell "B" 72 Weight of .005 Pounds

Finish No comments

COMMENTS: A. Workmanship No comments

B. Machining No comments

C. Design Quality No comments

D. Manufacturing Method & Quality Stamped from .011 sheet stock.

MICROSTRUCTURE: Although close to a high brass alloy some beta was noted. No inclusions or other defects.

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Part Name Worm Wheel - Turret Drive

Laboratory Serial No. 264058 Date

X-RAY EXAMINATION: XCED NO. H-281 Revealed a sound structure with some space due to contraction between steel hub and bronze worm gear - Good quality.

MACRO EXAMINATION: Macro inspection, photograph 6441, showed a medium to fine grain size. Quality of metal was good.

CHEMICAL ANALYSIS: Cu 89.7%, Fe 2.9%, Al 7.5%, Si 0.10%

Compares to ASTM B-148-41T

HARDNESS VALUE: Rockwell "F" 74 Weight of Pounds

Finish Satisfactory finishing

COMMENTS: A. Workmanship Satisfactory

B. Machining Very rough machining cuts taken on aluminum bronze gear teeth.

C. Design Quality Good mechanical locking of bronze to steel hub by slots located in steel hub.

D. Manufacturing Method & Quality Aluminum-Bronze alloy cast in a permanent mold around steel forged hub. Good quality - As-cast condition. Non-heat treatable alloy.

MICROSTRUCTURE: Very good typical structure showing single phase alpha alloy - classed as alpha type aluminum bronze.

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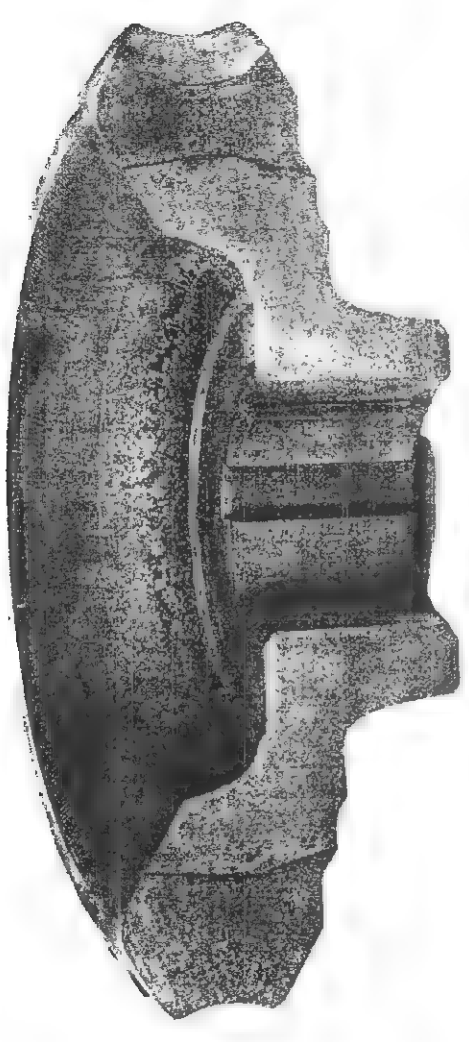

6444 - MACRO SECTION OF WORM WHEEL TAKEN FROM THE TURRET DRIVE

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Part Name Starter Switch Contact Point Ass'y.

Laboratory Serial No. 263840 Date

X-RAY EXAMINATION: XCED NO. Omitted

MACRO EXAMINATION:

CHEMICAL ANALYSIS: Cu 94.2%, Sn 3.4%, Zn Bal

Compares to

HARDNESS VALUE: Rockwell "B" 77 Weight of .004 Pounds

Finish Smooth uniform rolled sheet.

COMMENTS: A. Workmanship Satisfactory

B. Machining Edges of part free from burrs.

C. Design Quality Satisfactory - ample section thickness and bend radii allowed in forming.

D. Manufacturing Method & Quality Stamped from sheet - Good quality.

MICROSTRUCTURE:

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TUNGSTEN (Contacts)

Contact Points - Voltage Regulator

At the regulator end, the stud wafer was tungsten and the movable contact was silver.

The spectrographic analysis of the movable point is

Ag - Major portion	Pb - 0.1 - 1
Cu - 0.1 - 1%	Fe - 0.1 - 1
Sn - 0.1 - 1%	Zn - 0.1 - 1

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TABLE I

DATA ON NON FERROUS COMPONENTS USED IN THE T-34 TANK

Alloy Base	Part Name	Group	Compares to		Form
			Alcoa	Federal	
Alum.	Camshaft Brg. Block	I	356	QQ A 371	Perm. Mold Casting
Alum.	Camshaft Brg. Cap	I	356	"	Perm. Mold Casting
Alum.	Oil Pump Body	I	356	QQ A 371	Perm. Mold Casting
Alum.	Camshaft Drive Pinion Brg. Support	I	356	QQ A 371	Semi Perm. Mold Casting
Alum.	Accessory Drive Shaft Brg.	I	356	QQ A 371	Semi Perm. Mold Casting
Alum.	Generator Coup. Drive Shaft Center Bearing	I	356	QQ A 371	Semi Perm. Mold Casting
Alum.	Lower Camshaft Drive Gear Brg.	I	356	QQ A 371	Semi Perm. Mold Casting
Alum.	Generator Coup. Drive Shaft End Brg.	I	356	QQ A 371	Perm. Mold Casting
Alum.	Generator Drive Shaft Brg. Sleeve	I	356	QQ A 371	Semi Perm. Mold Casting
Alum.	Oil Pan	I	356	QQ A 601	Sand Casting
Alum.	Crankcase	I	356	QQ A 601	Sand Casting
Alum.	Cylinder Block	I	356	QQ A 371	Sem. Perm. Mold Casting
Alum.	Cylinder Head	I	[redacted]	QQ A 601	Sand Casting
Alum.	Water Pump Impeller	I	356	QQ A 601	Sand Casting
Alum.	No. 1 Main Crankshaft Brg. Cap	I	356	QQ A 371	Perm. Mold Casting
Alum.	Switch Box - Gun Safety	[redacted]	B195	QQ A 596	Perm. Mold Casting
Alum.	Air Cleaner to Intake Manifold Elbow	II	113	QQ A 596	Sand Casting
Alum.	Upper Transmission Case	III	645	None	Sand Casting
Alum.	Lower Transmission Case	III	645	None	Sand Casting
Alum.	Bracket Tach. Mtg.	IV	85	QQ A 591	Die Casting
Alum.	Fuel Transfer Pump Body	[redacted]	-	None	Sand Casting
Alum.	Engine Piston	V	-	None	Forging
Alum.	Crankshaft Main Bearing Cap	VI	14S	Class 5 QQ A 367	Forging
Alum.	Piston Pin Plug	VI	14S	QQ A 367	Bar Stock
Alum.	Fuel Transfer Pump Drive Shaft Body Seal	VI	17S	QQ A 363	Bar Stock
Alum.	Cyl. Head Gasket	VII	2S	QQ A 411	Sheet Stock
Alum.	Water Filler & Pressure Cap Housing	VII	-	None	Sand Casting
Zinc	Periscope Body	I	Zumak 2	None	Die Casting
Zinc	Speedometer Odometer Body	II	Zamak 3	Comp. A QQ Z 363	Die Casting
Zinc	Fuel Tank Selector Valve Body	III	Zamak 5	Comp. B QQ Z 363	Sand Casting
Zinc	Fuel Tank Selector Air Precourization Valve	III	Zamak 5	Comp. B QQ Z 363	Perm. Mold Casting
Copper	Main Brg. Thrust Rod Washer	I	Muntz	Comp. E QQ B 611	Sheet Stock
Copper	Starter Switch Contact Point Assy.	II	Bronze-Tin	Comp. A QQ B 746	Sheet Stock
Copper	Conn. Rod Pin Washer	I	Muntz	Comp. E QQ B 611	Sheet Stock
Copper	Fuel Tank Selector Valve	I	Muntz	Comp. E QQ D 611	Rod and Bar Stock
Copper	Turret Dr. Worm Wheel	III	Bronze-Alum.	Comp. B QQ B 671	Perm. Mold Casting
Copper	Periscope Plate	IV	Silicon Bronze	None	Sand Casting

T4 - Solution heat treated.

T6 - Solution heat treated and then artificially aged.

* "less than"

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TABLE I

DATA ON NON FERROUS COMPONENTS USED IN THE T-34 TANK

Heat Treat	Weight of Part	Hardness Value	Chemical Composition Per Cent - %													
			Si	Cu	Fe	Mg	Mn	Ti	Cr	[illegible]	Ni	Pb	Sn	Al	Zr	Cd
T6	.92	BHN 93	8.7	.15	.51	.31	.43	*.10	*.1	*.1	*.5	-	-	Bal.	-	
T6	.42	BHN 93	8.7	.15	.51	.31	.43	*.10	*.1	*.1	*.5	-		Bal.	-	
T6	4.56	BHN 92	8.5	*.6	.53	.23	.27	Nil	*.04	*.5	*.5	-	-	[illegible]	*.05	
T6	1.56	BHN 96	8.2	*.6	.47	.26	.24	Nil	*.04	*.5	*.5	-		Bal.	*.05	
T6	1.56	BHN 100	8.1	*.6	.49	.23	.26	Nil	*.04	*.5	*.5	-	-	Bal.	*.05	
T6	1.42	BHN 93	8.7	*.6	.52	.30	.28	Nil	*.04	*.5	*.5	-	-	Bal.	*.05	
T6	1.80	BHN 100	8.3	*.6	.52	.30	[illegible]	Nil	*.04	*.5	*.5	-		Bal.	*.05	
T6	.44	BHN 100	9.2	*.6	.60	.30	25	Nil	*.04	*.5	*.5	-	-	[illegible]	*.05	
None	1.46	BHN 74	7.7	*.6	.60	.30	.25	Nil	*.04	*.5	*.5	-	-	[illegible]	*.05	
None	54.0	BHN 70	8.1	Tr	.1-1	.1-1.0	.1-1-0	*.1	Nil	*.5	*.5	-	-	Bal.	Nil	
None	212.0	BHN 73	10.7	Tr	.1-1	.1-1.0	.1-1-0	*.1	Nil	*.5	*.5	-	-	Bal.	Nil	
T6	59.0	BHN 93	8.7	Tr	.1-1	.1-1-0	.1-1-0	*.1	Nil	*.5	*.5	-	-	Bal.	Nil	-
T6	[illegible]	BHN 80	8.7	Tr	.1-1	.1-1-0	.1-1-0	*.1	Nil	*.5	*.5	-	-	Bal.	Nil	
T6	.24	BHN 96	8.3	Tr	.44	.25	27	*.2	-	*.2	*.5	-	-	Bal.	-	
T6	-	BHN 100	8.7	*1.0	.52	.11	.28	-	-	*.9	*.5	-	-	Bal.	-	
T6	1.10	BHN 105	1.6	5.7	1.3	.20	.53	-	-	*.5	*.2	-	-	Bal.	-	
None	10.3	BHN 77	2.3	7.4	.1-1	*.1	Tr	*.1	Nil	2.0	*.5	-	-	Bal.	Nil	
None	118.5	BHN 74	Tr	3.5	Tr	*.1	Nil	-	-	13.3	-	-	-	Bal.	-	
None	115.5	BHN 86	Tr	2.7	Tr	*.1	Nil	-	-	13.5	-	-	-	Bal.	-	
-	.10	BHN 102	4.8	3.8	.82	.44	.30	-	-	.62	*.2	-	-	Bal.	-	
-	1.00	BHN 76	4.9	2.1	.65	*.1	.50	-	-	*.5	.2	-	-	Bal.	-	
T5	5.26	See Fig.#	-	3.6	1.5	2.2	.17	*.05	Nil	Nil	2.7	-	-	Bal.	Nil	
T4	4.22	BHN 105	.6	4.4	.39	.39	*1.0	*1.0	*1.0	*.5	*.5	-	-	Bal.	Nil	
T4	.08	BHN 99	1.15	5.8	1.08	48	.63	*.05	Nil	Nil	Nil	-	-	Bal.	Nil	
T4	-	BHN 99	-	4.2	.38	.41	.42	-	-	*.5	*.2	-	-	Bal.	-	
	1.30	BHN 44	*.1	*.1	.16	*.1	*.1	*.1	*.1	*.5	*.5	-	-	Bal.	-	
None	1.12	BHN 100	.83	8.2	1.15	*.1	.25	-	-	25.4	*.8	-	-	Bal.	-	
None	2.17		-	2.7	*.05	*.02	-	-	-	Bal.	-	[illegible]	*.005	3.0	-	.007
None	.30	-	-	Tr	*.05	.10	-	-	-	Bal.	-	.013	*.005	4.8	-	.007
None	.30	-	-	1.4	*.05	*.02	-	-	-	Bal.	-	.008	*.005	4.2	-	.007
None	.88	-	-	1.4	*.05	*.02	-	-	-	Bal.	-	.007	*.005	4.7	-	.008
None	.05	RB 47	-	61.6	Tr	-		-	-	Bal.	Tr	Nil	Nil	-	-	-
None	.004	RB 77	-	94.2	-	-	-	-	-	Bal.		-	3.4	-	-	-
None	.005	RB 72	-	62.0	Tr	-	-	-	-	Bal.	Tr	Nil	Nil	-	-	-
None	0.40	RB 63	-	58.3		-	-	-	-	Bal.	-	[illegible]	-	-		-
None	-	RB 74	.10	89.7	2.9	-	-	-	-	-	-	-	-	7.5		-
None	1.62	RB 63	2.3	79.5	-	-	-	-	-	Bal.	-	-	-	-	-	

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METALLURGY

Bearings

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METALLURGY REPORT

BEARINGS AND RUBBING SURFACES
(Non-Ferrous)

The connecting rod and main bearings are of nominal composition as follows:

Lead	25%
Copper	75%

They are cast on steel back of Rockwell B hardness 65 to 86, which is quite a range. Structure of the lining is fairly good. The 39 Rockwell C journal used in this engine should be quite satisfactory for operation against these bearings.

The following bushings, all bronze castings, have been analyzed with results as shown:

Oil pump shaft bushing

Copper	88.5%
Tin	8.7%
Lead	.2%
Zinc	Balance
R "B"	61

Articulating rod bearing

Spectrographically similar to above.

Connecting rod upper end bushing

Spectrographically similar to above.

The only remarkable thing about this composition of bronze for these applications is that it contains so little lead. Normal procedure here would be to use S.A.E. 791, or if pounding were too heavy for this material, S.A.E. 792. If a casting were essential, S.A.E. 64 or 660 would probably be used.

The water pump shaft bushing appears, from its spectrographic analysis, to be a silicon bronze, containing no manganese or aluminum and minor amounts of zinc. There appears to be more lead present here than in most silicon bronzes. Silicon bronze is not commonly used as a bearing. Its main characteristics are good resistance to corrosion by some aqueous solutions, high strength and hardness (Rockwell B 69 in this case). This

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hardness is the most probable reason for specifying it here. Information on expected loads would throw some light on this. It generally requires good lubrication, and in this case received it.

Camshaft bracket composition elsewhere reported is rather a structural than a bearing alloy. The unhardened camshaft journals, Rc26, will probably wear more heavily than we would think desirable, but it would be a long time before this seriously affected the operation of the tank.

Fuel Transfer Pump Shaft Bushing

This part is a low-tin, high-lead bronze with a remarkably high percentage of nickel.

Composition found was as follows:

Copper	68.3%
Tin	4.0%
Lead	24.5%
Nickel	3.1%

This almost classifies as a copper-lead. It is unusual to make so fragile a part as this of such a high-lead material without a steel back. The addition of the high nickel content was undoubtedly made to strengthen and harden the copper base matrix. This aim was achieved; hardness was Rockwell F64, which is equivalent to a Brinell hardness of 57-58 on the 500 kilogram scale. The comparative figure without the nickel would be about 50.

Lead dispersion was excellent. The piece had a lead colored fracture, indicating good cleanliness of the melt.

The reason for use of so much lead in the alloy was doubtless the fact that the bushing is lubricated only with Diesel fuel oil. Light load permits limited hardness. In accordance with the composition, a hardened journal was used.

If we had a similar problem to solve, we would produce a flanged, steel-backed bushing out of a strip, using much the same bearing alloy without the nickel.

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METALLURGY

Protective Coatings

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PROTECTIVE COATINGS

Protective coatings found on the tank engine were examined and the results tabulated. The following pages include the type of coating and the practice generally followed in the U. S. for coating similar engine parts.

25X1A

Zinc and lead were the only metallic coatings found. The zinc coating on the steel tubing used to distribute compressed air for starting was found to be .0004 in. thick. [redacted] Some of the oil and air valves were lead dip coated. The scavenge oil control valve consisted of a casting to which steel outlet and inlet lines were welded. The assembly was then lead dipped. No cadmium, nickel, or chromium plating was found.

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Part Name	Type of Coating	U.S.A. Practice
Manifold-exhaust (outside)	Organic coating	Painted with engine after assembly
Manifold-intake (outside)	Organic coating	Painted with engine after assembly
Valve cover (inside)	Phenolic	Phenolic or alkyd
Valve cover (outside)	Gray enamel	Painted with engine after assembly
Oil filter inlet line (from pump)	Zinc plate	Lead-tin alloy hot dip coating
Fuel distributing lines	Zinc plate	Lead-tin alloy hot dip coating
Water inlet line-pump to block		
Outside	Gray enamel	Painted with engine after assembly
Inside	No coating	No coating
Oil filter straps	Zinc plate	Cadmium or zinc plate
Valve springs	Zinc plate	Stainless steel, Cd plate or Lionoil coating
Valve spring retainer	Black oxide	No finish
Fuel injectors	Black oxide	--
Lubrication oil return line (camshafts to oil pan)	Zinc plate	Lead-tin alloy hot dip coating
Accelerator linkage rod (engine upper bellcrank to injection pump governor)	Zinc plate	Cadmium or zinc plate
Accelerator linkage clevises	Black oxide	Cadmium or zinc plate
Oil (fuel) feed line, ends	Black oxide	Cadmium or zinc plate
Oil (fuel) feed line, tube	Zinc plate	Lead-tin alloy hot dip coating

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PROTECTIVE COATINGS
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Part Name	Type of Coating	U.S.A. Practice
Cylinder head studs	Black oxide	No finish
Inspection plate		
Front-upper-(inside)	Phenolic	No finish
Interior of crankcase	Phenolic	No finish
Oil pan (inside)	Phenolic	No finish
Hold down bolts - camshaft	Black oxide	No finish
Valve case cover - hold down studs	Black oxide	No finish
Generator case & straps	Zinc plate	Paint
Water pump housing (inside)	Phenolic	No finish
Oil line baffle		
(inside oil pan)	Black oxide	No finish
Oil seal cover	Black oxide	No finish
Water inlet & outlet fittings	Phenolic	No finish
Fuel injection pump fittings	Black oxide	Cd or Zn plate
Oil filter bolt	Black oxide	No finish

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FUEL and LUBRICANTS

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FUEL AND LUBRICANT ANALYSES REPORT

Samples of fuel and lubricants removed from the G812 Russian T34 tank were tested and the results compared with those in the Aberdeen report. The following evaluation of oils and greases was made:

1 - Transmission Oil and Engine Oil

The analysis of the transmission oil as obtained by the Fuels and Lubricants Laboratory was compared with the Aberdeen Automotive Laboratory results on a Russian tank transmission oil in 1942. As can be seen from Table I, there has been very little change. The oil is essentially on SAE 50 engine oil with no additives. (A small amount of fatty oil appears to be present in the transmission oil analysis. Since not enough is indicated to make any substantial difference, the fatty oil may be an impurity. 25X1A

2 - In Table I there is also a comparison of the 1942 Aberdeen results on the engine oil [redacted] Except that the pour point is substantially lower than that of the above mentioned transmission oil, the present engine oil resembles both the transmission oil and the 1942 engine oil.

3 - Diesel Fuel Oil

Table II shows the comparison of data on fuel oils as reported by Aberdeen in 1942 [redacted] The data show that the oils are in every way similar and that a reasonably good grade of fuel was being used in both cases. 25X1A

4 - Final Drive Housing Oil 25X1A

Table III shows [redacted] analysis of the final drive housing oil. This appears to be an SAE 80 gear oil with some sodium base grease mixed in, probably as an impurity. The oil itself has no extreme pressure or other additives.

5 - Texas Company Analysis of Russian Oils

Table IV shows part of the Texas Company analytical data on various Russian oils as reported in 1943. This table is included because it indicates that the tendency at that time was to use straight mineral oils of the same general viscosity ranges as were found in the present T34 tank. It seems of more than passing interest to the writer that no advantage appears to have been taken of the considerable strides that have been made in the fields of detergent and other type additives.

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6 - In Table V a partial report of the Texas Company data of 1943 on various Russian greases is included. The reason no comparisons have been made directly between these greases and the greases found in the Russian tank, which is being investigated, is that the two groups of greases bear no general relation to each other. Of the three greases reported by the Texas Company, only one is calcium soap base, whereas all of the ones found in T34 tank have a calcium soap base. Whereas melting point appeared to be of some interest in the early greases, it appears that the present Russian thinking does not place much value on this property.

7 - Data on Calcium Soap Base Greases with a Mineral Oil Base

Table VI shows the two greases that most closely resemble those in Table V. The wheel hub lubricant consists of an SAE 10W oil thickened with 11% calcium soap. This is a type of grease quite often encountered in American practice. The coil spring suspension case has an extremely hard smooth orange colored grease made from SAE 10W oil thickened with 27% calcium soap. Except for the presence of a substantial amount of asphaltic material of unknown source, this grease is not unusual. The source of the asphalt could not be determined because of the large amount of debris such as dirt, rocks, canvas, etc. present in the original sample.

8 - Analysis of Grease Containing Wool Fat

Table VII shows the analysis of three greases, all of which contain a substantial amount of wool fat. The turret bearing grease contained 20.7% wool fat in addition to 3.7% calcium soap in which there was a trace of sodium soap. This material also contained 75% of either a very soft petrolatum or a mixture of petrolatum and oil. The end result was grease with a dropping point of 136°F. This grease should be very useful where water resistance is needed, but would seem of doubtful value if high temperature adhesion were required. Although the sample of water pump grease received was insufficient to make a detailed analysis, it appeared to be similar to that found in the turret bearing. The grease in the suspension shaft inside the hull was a combination of three materials. These were a grease similar to that found in the water pump, a grease similar to that found in the wheel hub, and a heavy mineral oil which did not appear to have separated from the greases. The three were not well mixed and it appears that this unit was lubricated with whatever happened to be handy at the moment.

In general, two conclusions can be reached from the analyses of the lubricants in the subject T34 tank:

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1 - The Russians have not taken advantage of recent research in oil additives.

2 - Water insolubility of the grease used in the T34 tank seems to be of prime consideration, with less temperature resistance being required.

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TABLE I

COMPARISON OF ABERDEEN AUTOMOTIVE LABORATORY RESULTS REPORTED IN 1942 WITH [redacted] DATA ON 1951 TANK OILS. 25X1A

25X1A

Test	Transmission Oil		Engine Oil	
	Aberdeen Lab. No. 4077	[redacted]	Aberdeen Lab. No. 4075	[redacted] 25X1A
Pour Point	+70°F	+70°F	+20°F	+10°F
Naphtha Insol. (Weight)	0.40%	0.28%	0.083%	0.30%
Chloroform Insol. (Weight)	0.27%	0.20%	0.075%	0.10%
Conradson Carbon Residue	1.10%	0.665%	0.80%	
Neutralization Number	0.159	0.12(No fatty acid)	0.092	0.03
Viscosity @ 100°F CS	342		340	
Viscosity @ 100°F SSU	1580-1600	1274	1572	1275
Viscosity @ 210°F CS	21.5		22.1	
Viscosity @ 210°F SSU	104.4	103	106.9	92
Viscosity Index	94	99	86	79
Dilution	-		Some indicated	
Ash	0.26%	0.131%	0.034%	0.04%
Asphaltenes	0.13%			
Saponification No.		2.50		
Calculated Fatty Oil		1.5-2.0%		
Copper Strip Corrosion				
@ 212°F		Nil		Nil
@ 300°F		Nil		Nil
% Sulphur		0.10%		0.14%
% Chlorine		Nil		
% Lead		Nil		
% Phosphorous		Nil		
SAE Rating		90		50

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TABLE II

COMPARISON OF DATA ON FUEL OILS AS REPORTED BY THE AUTOMOTIVE LABS OF THE ABERDEEN PROVING GROUNDS IN 1942 AND [redacted] IN 1951.

25X1A

Test	Aberdeen Lab. No. 4076	[redacted]
Aniline Point	146.8°F	151.5°F
Specific Gravity 60/60	0.8658	0.858
A.P.I. Gravity	38.3	33.42
Diesel Index	49.8	50.63
Viscosity @ 100°F SSU	38.3	39.0
Copper Strip Corrosion	Nil	Nil
Flash Point (PM)	170°F	
Flash Point (COC)		210°F
Pour Point	-10°F	0°F
Cloud Point	-12°F	
Naphtha Insol.	0.009%	Nil
Carbon Res.	0.024%	0.210%
Ash	0.004%	Nil
Water & Sediment	Nil	Nil
Distillation		
I BP	392°F	385°F
10%	446	461
20%	470	488
30%	489	505
40%	508	519
50%	528	533
60%	552	548
70%	576	566
80%	609	588
90%	666	630
E.P.	718	654
Rec.	98%	96.5%
Res.	0.9%	3.5%
Gross Heat of Combustion		19,579 B.T.U./lb.
Net Heat of Combustion		18,338 B.T.U./lb.

25X1A

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25X1A

TABLE III

[redacted] ANALYSIS OF FINAL DRIVE HOUSING OIL

Test	[redacted] 25X1A
Viscosity @ 100°F SSU	391.9
Viscosity @ 210°F SSU	55.75
Viscosity Index	85
S.A.E. No.	80 Gear Oil 20 Motor Oil
Pour Point	-50°F
Sulfur	0.121%
Ash	0.769% (Mostly sodium and iron)
Copper Strip Corrosion	Nil
Neutralization No.	0.38
Naphtha Insolubles	10.4%
Benzene Insolubles	0.2%
Almen Load	6 lbs.
Nature of Naphtha Insolubles	Mostly sodium base grease in clots.

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TABLE IV

TEXAS CO. REPORT OF RUSSIAN OILS ISSUED 2-26-43

(Abstracted)

	T 100 Engine Oil	TD Avtol. 105 No. 18	TD 106 Aviation Oil	TD 107 Spindle Oil Recoil Mech.
Gravity API	25.0	20.9	24.9	24.8
Flash COC	520	435	520	360
Fire COC	590	510	600	395
Viscosity @ 100 SSU	1813	1383	1908	137.4
Viscosity @ 210 SSU	114.1 (23.7CS)	82.5 (16.2CS)	137.9 (29.1CS)	41.0 (4.5CS)
Approx. SAE Grade	60	50	70	-
V.I.	84	40	104	53
Pour ^{o}F ASTM	+10	+10	-10	-45
Copper Strip @ 212°F	Neg.	Neg.	Neg.	Pos. Black
Carbon Residue	0.67	0.84	0.74	0.13
Neutral No.	0.06	0.30	0.06	0.76
Saponification No.	0.7	2.0	1.6	9.3
Ash	.01	0.13	Trace	0.01
Total Fatty Acids %	0.12	0.91	0.22	0.35
Neutral No.	Insufficient sample	140	Insufficient sample	141
Total Sulphur %	0.11	0.19	0.11	0.52
Corrosion Copper Strip	Positive (Peacock)	Neg.	Positive (Peacock)	Positive (Black)

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TABLE V

RUSSIAN GREASES AS ANALYZED IN THE TEXAS CO. REPORT OF 2-26-43

(Abstracted)

	TD 103 Konstalin W.B. Grease (Russian Lub.)	TD 104 Colidol SP. Grease	TD 108 Lub. Oil No. 8 (A Grease)
Appearance	Light Yellow Tan	Shiny Brown, Slt. Blue Bloom	Shiny, Dark Greenish blue
Melting Point °F	312	180	257
Penetration			
Unworked	239	233	399
Worked	240	239	383
Ash	3.2	1.5	1.2
Predominating Base	Sodium	Calcium	Sodium
Soap	27.8 (Na)	13.4 Ca 1.2 Mg.	11.1 (Sodium)
Oil Mineral	69.3	81.5	86.1
Tests on Oil (Unsaponified)			
Viscosity SSU @ 100	173	404	574
Viscosity SSU @ 210	42.8	51.4	59.9

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TABLE VI

DATA ON CALCIUM SOAP GREASES USED IN THE WHEEL HUB AND THE COIL SPRING SUSPENSION CASE OF A RUSSIAN T34 TANK

25X1A

Test	Wheel Hub [redacted]	Coil Spring Susp. Case [redacted]
Dropping Point	167°F	176°F
Penetrometer	286	191
% Soap	11.37%	27.6%
Type of Soap	Calcium	Calcium
Oil Vis.@ 100°F SSU	186.2	180.3
Oil Vis.@ 210°F SSU	45.1	43.6
Viscosity Index	89	63
Ash %	3.68% Majority Calcium and Iron	5.17%
Appearance		This was an extremely hard, smooth orange colored grease. Since it was full of debris such as dirt, rocks, sticks, pieces of canvas, etc., its exact composition was difficult to define. It contained a substantial amount of asphaltic material of unknown source.

25X1A

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25X1A

TABLE VII

ANALYSIS OF GREASES CONTAINING WOOL FAT

25X1A

Test	Turret Bearing [redacted]	Water Pump [redacted]	Suspension Shaft Inside Hull [redacted]
Dropping Point	136°F	138°F	157°F
Penetrometer	274	272	269
% Soap	3.71%	3.56%	9.63%
Type of Soap	Calcium (Trace Sodium)	Calcium (Trace Sodium)	Calcium
Ash	2.18%	0.84%	
Oil Vis. @ 100 SSU			521.1
@ 210 SSU			61.8
Viscosity Index			84
Foreign Material	1.34% (Mostly iron & Rust)		
Saponification No.	20.2		
Insoluble Fatty Acids	4.05%		
Combined Fatty Acids From Esters	4.97%		
Iodine No.	5.1		
Total Alcohols	11.39%		
Reichert Meissel No.	1.9		
Unsaponifiables	78.41%		
Acetyl Value	4.9		
Melting Point of unsaponifiables	104°F		
Notes:	This grease is apparently about 3.7% soap 20.7% wool fat and the remainder is either a very soft petrolatum or a mixture of petrolatum and oil.	Apparently similar to turret bearing grease; insufficient sample prevented duplicating tests.	This grease is a mixture of three materials.: 1. Similar to water pump grease. 2. Similar to wheel hub grease. 3. A heavy mineral oil apparently not separated from the grease.

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RUBBER PARTS

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RUBBER PARTS ANALYSIS

Natural Rubber

Parts made of natural rubber were of a good quality compound with good general properties. Electrical connection insulators, for instance, had a tensile strength of approximately 1800 psi and an ultimate elongation of 650%. The following parts tested were found to be of natural rubber:

1 - Electrical connection insulators
2 - Outer cover layer on oil and water line connector hoses
3 - Cylinder sleeve water seal
4 - Bogie wheel tires

Neoprene Type Synthetic Rubber:

All rubber parts on the tank which would ordinarily be subjected to contact with oil or fuel were made of a polychoroprene (neoprene) synthetic rubber. This particular polychoroprene is apparently the Russian synthetic Sovaprene, which is similar to our neoprene rubbers.

Samples of neoprene rubber were found to have comparatively poor tensile and elongation properties and good oil and heat resistance properties. The average tensile strength of the neoprene inner layer of oil and water line connector hoses was 400 to 800 psi with 50 to 200% elongation. This indicates that the stock is highly loaded with carbon blacks and other types of fillers. (This could be a means of conserving their rubber supply.) Oil resistance tests of the same sample showed 40 to 80% volume swell after 70 hours at 212°F in ASTM #3 oil. This is considered good for polychoroprene type compounds. Adhesive properties on all hose parts were very poor. (This factor may indicate a shortage of natural rubber for adhesive compounds or may represent what the Russians consider a satisfactory product.) Heat resistance tests conducted at 212°F for 70 hours show no appreciable loss in tensile strength, indicating good heat resistance. The following Cold Room tests on a neoprene sample (peep window head pad) were reported:

5 hours at - 40°F	flex OK
5 hours at - 65°F	flex OK
70 hours at - 40°F	flex OK
70 hours at - 65°F	sample broke

Parts made of neoprene are listed below:

1 - Connector hose from intake manifolding elbow to air cleaner duct and intake manifold
2 - Final drive dust seal

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3 - Grommet in connection from fuel line to injection nozzle
4 - Grommet in oil return line from head to crankcase
5 - Head-block water port gaskets
6 - Antenna anti-vibration gaskets
7 - Cylinder sleeve oil seal
8 - Inner layer of oil and water line connector hoses
9 - Peep window head pads

Buna S Synthetic Rubbers:

Samples of Buna S type rubber were found to have low tensile strength and fairly good elongation properties. This type of rubber was used for vibration and electrical insulation. A sample of 24 volt high current capacity wire insulation tested had a tensile strength of 490 psi, elongation of 525%, and a Durometer hardness of 60. Another sample, from a smaller wire, had a tensile strength too low to test, elongation of 450%, and Durometer hardness of 60. Another Buna S sample, from the driver's periscope vibration insulator, had a tensile strength of 600 psi and appeared to be from a stock highly loaded with fillers. Tests on the suspension arm bumper indicated that an exceptionally volatile plasticizer was used in the compound. The bumper examined showed indications of having been subjected to extreme heat, either from direct contact with fire or from high and frequent impact. Cold Room tests on a Buna S sample (generator drive coupling) revealed the following:

5 hours at - 40°F	flex OK
5 hours at - 65°F	flex OK

The following parts tested were of Buna S:

1 - Driver's periscope vibration insulator
2 - Instrument panel vibration insulators
3 - Suspension arm bumpers
4 - Generator drive coupling
5 - Periscope handle grip
6 - Ammunition cushions
7 - Oil, fuel, and air line vibration insulators
8 - Insulation on electrical wiring

The following report represents further analysis on miscellaneous rubber parts (non-oil resistant applications) removed from the tank.

1 - PHYSICAL PROPERTIES

The physical properties of the parts as tested appear to be approximately 30% lower than those generally specified for current automotive rubber parts and the specification limits for U. S. tank rubber parts built for World War II, and 50% lower than those being established for the current tank building program.

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The figures of 30 and 50% are in addition to a 25% age or service loss generally allowed on parts of this type as compared to the calculated original physical values.

The higher standards affecting our current tank rubber parts are based on an Ordnance request that oil resistance and flexibility at -65°F be specified on a large majority of the rubber parts required for both current and future tank building programs.

All parts tested hardened far beyond our specification limits at both -35 and -65°F.

The majority of parts showed excessive bloom. All parts ignited and burned more freely than U. S. "general use" type polymer base compounds.

2 - FABRICATION TECHNIQUE

(a) Extruded Parts

Indications from the parts examined in regard to "rating the fabrication technique" are that the parts were:

1 - run by inexperienced processing or machine hands,
2 - made from poor extrusion stocks,
3 - extruded at extremely high speeds intentionally.

The above is based on the extreme surface roughness, both inside and outside, of the parts submitted.

(b) Molded Parts

All molded parts indicated good molding equipment and technique with the exception that little time was spent for trimming the parts. This applies to both functional and non-functional items.

3 - SOURCE AND PART IDENTIFICATION

No source of manufacturer or part identification, such as part number, was apparent on any of the parts examined.

4 - GENERAL SERVICE CONDITIONS

With the exception of the suspension bumper (item #3) none of of the parts covered by this analysis was subjected to severe service conditions.

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RUBBER PARTS - RUSSIAN BUILT TANK

1 - Vibration Insulator - Instrument to Cockpit

Method of Fabrication - Molded - Polymer Indicated - GRS Type

Durometer	56/62	Flame Test	Burns readily
Tensile & Elong.	--	Spec. Gravity	1.30
Tear	poor	Appearance	slight bloom
Compression Set	16.9	Gen'l Condition	good

Comments: When flame was extinguished, part gave off a very dense smoke which ignited very rapidly, indicating that an exceptionally volatile plasticizer was used in the compound.

2 - Vibration Insulator

Method of Fabrication - Extruded - Polymer Indicated - GRS Type

Durometer	58	Flame Test	Burns readily
Tensile & Elong.	368/100	Spec. Gravity	1.30
Tear	very poor	Appearance	very high sulfur bloom inside tube
Compression Set	--	Gen'l Condition	Fair

Comments: Very low quality stock and extremely rough extrusion.

3 - Suspension Bumper

Method of Fabrication - Molded - Polymer Indicated - GRS Type

Durometer	70	Flame Test	Burns readily
Tensile & Elong.	--	Spec. Gravity	--
Tear	fair	Appearance	See Comments
Compression Set	34	Gen'l Condition	" "
Resilience	51%		

Comments: When flame was extinguished, part gave off a very dense smoke which ignited very rapidly, indicating that an exceptionally volatile plasticizer was used in the compound. Approximately one half of this bumper simulated a "gummy" substance indicating that the part had either been in direct contact with fire or subject to terrific heat generated by high and frequent impact.

4 - Generator Drive Coupling

Method of Fabrication - Molded - Polymer Indicated - GRS Type

Durometer	75/80	Flame Test	Burns readily
Tensile & Elong.	--	Spec. Gravity	1.185
Tear	41.0	Appearance	See Comments
Compression Set	21.6	Gen'l Condition	Good

Comments: There were definite indications of "Case" or surface age hardening over the complete part and of minor abrasion effects around the drive pin holes on one side of the rubber coupling. Service conditions were apparently very moderate for this type part.

5 - Ammunition Rack Cushion

Method of Fabrication - Molded - Polymer Indicated - GRS Type

Durometer	58	Flame Test	Burns readily
Tensile & Elong.	--	Spec. Gravity	1.16
Tear	Fair	Appearance	Moderate Bloom
Compression Set	28.6	Gen'l Condition	Good

Comments: None

6 - Ammunition Box Cushion

Method of Fabrication - Molded - Polymer Indicated - GRS Type

Durometer	60	Flame Test	Burns readily
Tensile & Elong.	--	Spec. Gravity	1.115
Tear	--	Appearance	Moderate Bloom
Compression Set	47.2	Gen'l Condition	Good

Comments: None

7 - Periscope Handle Grip

Method of Fabrication - Extruded - Polymer Indicated - GRS Type

Durometer	60	Flame Test	Burns readily
Tensile & Elong.	547/150	Spec. Gravity	1.195
Tear	Poor	Appearance	See Comments
Compression Set	--	Gen'l Condition	" "

Comments: Very low quality - low age stock - extremely rough extrusion. Part had numerous surface cracks indicating part was highly stressed in assembly.

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8 - Peep Window Gasket

Method of Fabrication - Molded - Polymer Indicated - GRS Type

Durometer	55	Flame Test	Burns readily
Tensile & Elong.	640/475	Spec. Gravity	1.26
Tear	Poor	Appearance	Very High Sulphur Bloom
Compression Set	--	Gen'l Condition	Poor-See Note

Comments: Portion of gasket had apparently been subjected to oil.

9 - Peep Window Head Bumper Pad

Method of Fabrication - Molded - Polymer Indicated - Neoprene

Durometer	70	Flame Test	Does not supt. Combustion
Tensile & Elong.	563/275	Spec. Gravity	1.22
Tear	--	Appearance	Very High Sulphur Bloom
Compression Set	--	Gen'l Condition	Good

Comments: None

10 - Plug

Method of Fabrication - Molded - Polymer Indicated - GRS Type

Durometer	65	Flame Test	Burns readily
Tensile & Elong.	--	Spec. Gravity	1.19
Tear	--	Appearance	High Sulphur Bloom
Compression Set	--	Gen'l Condition	Good

Comments: None

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PLASTICS and FABRICS

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PLASTIC AND FABRIC PARTS

The following plastic and fabric parts were examined:

INJECTION PUMP CONNECTOR DISC

This part is made from what appears to be a grade C phenolic laminate. The filler plies are cotton duck and the piece seems to be of good quality. This type of laminate has been available commercially in Europe and the United States the past thirty years.

The workmanship on the part is poor, but sufficient. The only tools used on this part are bandsaw, drill press, file, and sand paper.

ANTENNA INSULATOR

This part is made from a macerated paper phenolic molding material. The part is compression molded and no attempt has been made to remove the mold flash. The material and part appear to be adequate for the application. This type of material has also been available commercially for the past thirty years.

COMPRESSED AIR TANK VALVE KNOB

This part is compression molded from a urea formaldehyde cellulose filled molding material. The material is of poor grade. It appears to be improperly mixed or contaminated with a white material of the same type. The mold flash has been very crudely removed.

The valve stem insert is cut from brass hexagon bar stock and is of poor design according to our standards. However, the part appears to be substantial enough to do the work required of it.

TURRET ELECTRICAL SUPPLY SLIP RING

The material used in this part is a rag filled phenolic compression molding stock. It is molded in two parts and the mold flash very crudely removed by hand. The part is of rugged design. The slip ring connectors are made of brass and are silver plated.

The molded inserts in this part are knurled and consistent with our design standard and practices. However, no more are used than necessary. Some connectors are riveted in with copper rivets. This possibly explains the use of such a high impact molding stock.

BATTERY CELL CASE

The construction of this cell case is of very poor design and indicates that there was not enough mold equipment available to follow better practice.

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The cell case is made by wrapping a hot asphalt impregnated loose cellulose paper around a mold. After this part was hardened, it is removed and sealed into a wooden case with more asphalt. The cover and plate assembly is consistent with our practice.

It is felt that this type of construction might not have too good a field life because of possible case distortion.

PILOT'S HEAD BUMPER

Consists of a sack made of flat cotton duck and a cotton sateen containing a coarse wool and hair felt pad.

This assembly is fastened to a metal plate.

The fabric has a coarse texture and apparently very little sizing. There is nothing new or exceptional about this material.

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SEALING COMPOUNDS

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SEALING COMPOUNDS

The following information was obtained concerning compounds used as seals on the G812 tank:

WATER SEAL FOR GUN OPENING IN TURRET

This compound was found to be iron oxide and a drying oil. It was applied to the outer edge of the gun opening in the turret before the turret was painted.

ELECTRICAL JUNCTION BLOCK INSULATING COMPOUND

This material was used on the fuse and junction block in the hull to insulate the back of riveted connectors. It consisted of coal tar pitch and clay.

PAN AND HEAD SEALING COMPOUND

This sealer contained a high percentage of red iron oxide in a drying oil. A red organic dye was also contained in the sealer.

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BALL and ROLLER BEARINGS - LIST

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COMPLETE LIST OF ROLLER AND BALL BEARINGS FOUND IN THE G812 TANK

No. per Tank			Inner Diameter	Outer Diameter	Width
1		Crankshaft thrust bearing, ball - [redacted]	100 mm	135 mm	25 mm
1	25X1B	Oil pump drive idler, ball - [redacted]	17	47	14
1	25X1B	Main accessory drive shaft, lower end - double ball, self-aligning - [redacted]	35	72	17
1		Main clutch, roller - [redacted]	110	174	30
25X1B 1		Main clutch, American made, ball - [redacted]			
2	25X1B	Steering clutch, inner, ball thrust - [redacted]	110	174	30
2		Steering clutch, double ball, self-aligning - [redacted]	60	150	35
2	25X1B	Fuel injector pump camshaft, ball - [redacted]	25	52	16
1		Water pump, ball - [redacted]	17	47	14
1		Generator, drive end, ball - [redacted]	25	62	17
1		Generator, commutator end, ball - [redacted]	25	52	15
1		Starter, commutator end, ball	25	52	15
2		Starter, drive end, double ball, self-aligning	45	85	19

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ROLLER AND BALL BEARINGS

No. per Tank			Inner Diameter	Outer Diameter	Width
		25X1B			
1		Transmission pinion, tapered roller - [redacted]	90 mm	160 mm	26 mm
1		Transmission pinion, ball thrust [redacted] 25X1B	100	172	56
1	25X1B	Transmission pinion, roller - [redacted]	85	180	40.5
1	25X1B	Transmission drive cross-shaft, double tapered roller - [redacted]	80	160	64
1	25X1B	Transmission driven cross-shaft, double tapered roller - [redacted]	80	160	64
1	25X1B	Transmission driven cross-shaft, roller [redacted] 25X1B	90	160	30
2		Transmission drive cross-shaft, roller (one American made) - [redacted]	60	150	35
2	25X1B	Transmission reverse idle gear, roller [redacted] (Hyatt type)	52	90	70
2	25X1B	Final drive, double tapered roller, self-aligning - [redacted]	110	200	53
2	25X1B	Final drive, tapered roller (American made) [redacted]	130	230	48
2		Final drive, tapered roller [redacted]	150	270	38
2		Final drive, pinion, roller - [redacted]	75	106	57

25X1B

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ROLLER AND BALL BEARINGS

No. per Tank			Inner Diameter	Outer Diameter	Width
		25X1B			
2		Track idler, ball (American made) [redacted]	86	180	40
25X1B 2		Track idler, inner bearing, roller [redacted] 25X1B	100	180	34
20		Bogie wheel, ball - [redacted]	80	170	39
25X1B 1		Turret rotating mechanism electric motor, commutator end, ball - [redacted]	12	32	10
25X1B 1		Turret rotating mechanism electric motor, drive end, ball - [redacted]	16	40	11
25X1B 1		Turret rotating mechanism worm shaft, drive end, ball - [redacted]	25	62	17
25X1B 1		Turret rotating mechanism worm shaft, pilot end, ball - [redacted]	20	52	15
25X1B 1		Turret rotating mechanism spur gear shaft, ball - [redacted]	20	52	15
25X1B 1		Ventilating fan, drive end, ball - [redacted]	12	32	10
1	25X1B	Ventilating fan, commutator end, ball thrust [redacted]	15	35	8
5		Tachometer bearings, ball all are small balls run on shaft with no inner race used			
1		Governor thrust arm, needle bearing, no separate inner race			

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ROLLER AND BALL BEARINGS

No. per Tank		Inner Diameter	Outer Diameter	Width
12	Fuel pump tappet assemblies, needle bearings, no separate inner race			
1	Ball thrust bearing in governor			
1	Turret ring, ball, thrust			
1	Commander's hatch, ball, thrust			
88	Total			
	Additional Bearing Balls Used			
9	Clutch release mechanism balls - 3 in each clutch			

Bearing Types Used

Ball-Radial -	36	
Thrust -	8	
Selfaligning (double row)	5	
Instrument - shaft is inner race	5	54
Roller-Straight (radial load)	6	
Tapered	9	
Double row tapered	2	
Spherical selfaligning	2	
Hyatt type	2	
Needle	13	34
Total		88

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25X1A

[redacted] REPORT ON ROLLER BEARINGS

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PHYSICAL LABORATORY REPORT
ON TEST NO. 369-J

Investigation on Antifriction Bearings Received from the Government on May 29, 1951

The following (8) bearings were analyzed to determine material, geometry and finish. Each bearing was identified by number as follows:

Bearing No.	Type	O.D.	Bore	Width	Photo
X-1	Spherical Self-Aligning Roller Final Drive Position-Type	200 mm (7.87 in.)	110 mm (4.33 in.)	53 mm (2.08 in.)	3997 3998
X-2A	Taper Roller Transmission Thrust Bearing Countershaft	140 mm (5.51 in.)	80 mm (3.15 in.)	28 mm (1.10 in.)	4000
*X-2B	Taper Roller (Same as 2A)	140 mm (5.51 in.)	80 mm (3.15 in.)	28 mm (1.10 in.)	-
X-3	Straight Roller Type R.N. Track Idler Inner Bearing	180 mm (7.08 in.)	100 mm (3.94 in.)	34 mm (1.34 in.)	4004
X-4	Straight Roller (Cage Assembly Only) Transmission Reverse Idler	90 mm (3.54 in.)	52 mm (2.04 in.)	70 mm (2.75 in.)	4003
X-5	Straight Roller Final Drive	150 mm (5.90 in.)	60 mm (2.36 in.)	35 mm (1.38 in.)	3999
X-6	Straight Roller Transmission Main Shaft End Bearing	160 mm (6.30 in.)	90 mm (3.54 in.)	30 mm (1.18 in.)	4001
X-7	Straight Roller (No Inner Race) Transmission Countershaft End Bearing	130 mm (5.12 in.)	75 mm (2.95 in.)	50 mm (1.97 in.)	4002

*Fatigue tested. See below

25X1B

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PHYSICAL LABORATORY REPORT
ON TEST NO. 369-J

Metallurgy:

Bearing No.	Outer Race	Inner Race	Rollers
X-1 - (A)	Steel - A.I.S.I. 52100	52100	52100
(B)	Hardness Rockwell "C" - 62.5	61-62	61-62
(C)	Non-Metallics - Good	Good	Fairly Good/Fair
(D)	Structure - Fine Carbide, Martensite Bainite	Fine Carbide, Martensite, Bainite	Fine Carbide, Martensite, Bainite
(E)	Fracture - O.K.	O.K.	O.K.
X-2 - (A)	52100	52100	51100
(B)	61	60-61	62-63
(C)	Good/Fair	Good/Fairly Good	Good
(D)	Fine Carbide, Martensite, Bainite	Fine Carbide, Martensite, Bainite	Fine Carbide, Martensite, Bainite
(E)	O.K.	O.K.	O.K.
X-3 - (A)	52100	52100	52100
(B)	61-62	61	64
(C)	Good	Good/Fairly Good	Good/Fairly Good

BALL AND ROLLER BEARING
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PHYSICAL LABORATORY REPORT
ON TEST NO. 369-J

Metallurgy:

Bearing No.	Outer Race	Inner Race	Rollers
X-3 - (D)	Fine Carbide, Martensite, Bainite	Fine Carbide, Martensite, Bainite	Fine Carbide, Martensite, Bainite
(E)	O.K.	O.K.	O.K.
X-4 - (A)	-	-	5130
(B)	-	-	43-46
(C)	-	-	-
(D)	-	-	Martensite
(E)	-	-	Poor
X-5 - (A)	Krupp *	-	52100
(B)	41-48	-	63-64
(C)	Fairly Good	-	Good/Fair
(D)	Martensite	-	Fine Carbide, Martensite, Bainite
(E)	O.K.	-	O.K.
X-6 - (A)	52100	52100	52100
(B)	61	62-63	62-63

* Note: This part had a thin carburized case.

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PHYSICAL LABORATORY REPORT
ON TEST NO. 369-J

Metallurgy:

Bearing No.	Outer Race	Inner Race	Rollers
X-6 - (C)	Good	Good	Fairly Good
(D)	Fine Carbide, Martensite, Bainite	Fine Carbide, Martensite, Bainite	Fine Carbide, Martensite, Bainite
(E)	O.K.	O.K.	O.K.
X-7 - (A)	52100	52100	52100
(B)	62-63	63	62-63
(C)	Good	Good	Fairly Good
(D)	Fine Carbide, Martensite, Bainite	Fine Carbide, Martensite, Bainite	Fine Carbide, Martensite, Bainite
(E)	O.K.	O.K.	O.K.

Cages:

The cage for the tapered roller bearing X-2 was #1010 steel and had a thin case. The cage for the spiral roller bearing X-4 was #1010 steel.

All other cages were bronze.

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PHYSICAL LABORATORY REPORT
ON TEST NO. 369-J

Geometry:

Brg. No.	Race Runouts: Inner ID to Outer OD	Race Runouts: Outer ID to Outer OD	Race Runouts: Inner ID to Inner OD	Out of Round: Outer Race ID	Out of Round: Inner Race ID	Out of Round: Rollers	Out of Parallel Between Faces: Inner Race	Out of Parallel Between Faces: Outer Race	Radial Clearance	Roller Size Variations: Length	Roller Size Variations: Dia.
X-1	.0015	.0008	.0003	.0003	.0000	.00005	.0002	.0001	.0015	.0011	.0050
X-2A	.0013	.0017	.0005	.0015	.0001	.00005	.0010	.0005	-	.0021	.0011
X-3	.0025	.0057	.0035	.0050	.0035	.0025	.0037	.0020	.004 to .0095	.0020	.0035
X-4	No Inner or Outer race received.					.00005				.0085	.0022
X-5	.0010	.0018	.0003	.0000	.0003	.00005	.0001	.0008	.007	.0028	.0002
X-6	.0010	.0030	.0006	.0030	.0000	.00005	.0004	.0006	.003 to .0042	.0012	.0003
X-7	No Inner race received					.0004				.0007	.0004

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PHYSICAL LABORATORY REPORT ON TEST NO. 369-J

Surface Finish:

Profilometer Readings - Micro Inches

Bearing No.	Inner Race OD	Inner Race ID	Faces	Outer Race OD	Outer Race ID	Roller Bodies
X-1	16	42	10	35	14	9
X-2	35	21	20	26	30*	18
X-3	15	35	17	25	12*	6
X-4						3
X-5	18	35	21	21	26	10
X-6	24	22	11	10	13*	24
X-7					52	6

*Readings taken on original finish. All other readings taken over contacting surfaces.

Conclusion:

Metallurgy

With the exception of bearing X-4 (flexible coiled roller), which was made of 5130 steel and of poor quality, and bearing X-5, whose outer race was made of Krupp steel with a very thin case, all other bearings were of 52100 through hardening steel and of good quality.

Parts were fabricated by forging methods, predominately pancaking or upsetting of bar stock. The flow lines in most cases intersected the raceway at a fairly high angle which is considered good practice.

Geometry

Race Runout - Fairly good on all except X-3 which had .0057 maximum on outer race.

Out of Round - Fairly good except:
Outer Race - Maximum on X-3 .005
Inner Race - Maximum on X-3 .0036
Rollers - Maximum on X-3 .0025
End Faces - Good except X-3 (.0037)

Rollers - Diameter size variation poor on X-1 (maximum .005) and X-3 (.0035)

Surface Finish

	I.D.	O.D.
Inner Races	O.K.	O.K. except X-2 (35 mu)
Outer Races	O.K. except X-7(52 mu)	O.K.
Rollers		O.K.

It should be noted that these bearings have been in service and could show some distortion. A certain amount of corrosion and wear is apparent.

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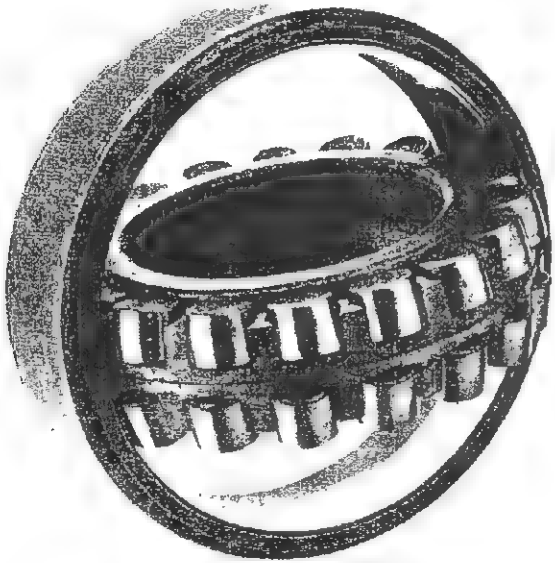

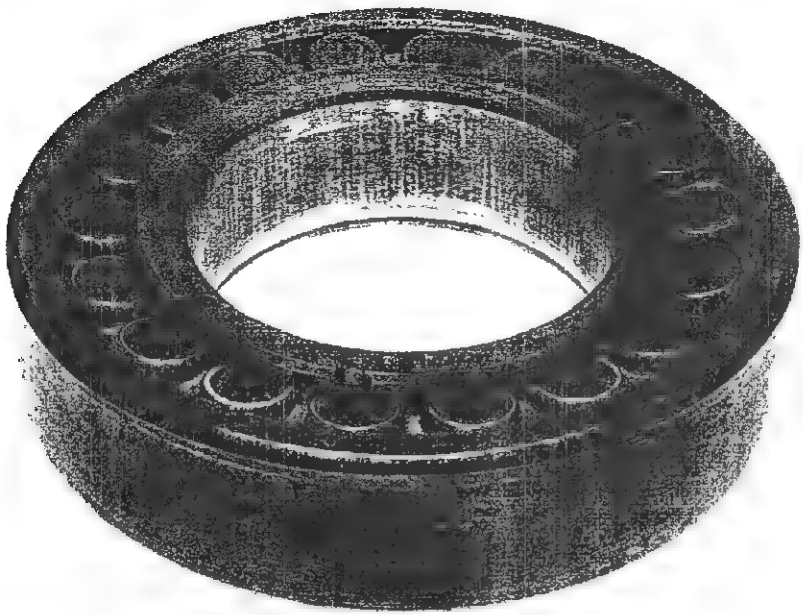

BEARING X-1 - [redacted] 25X1B

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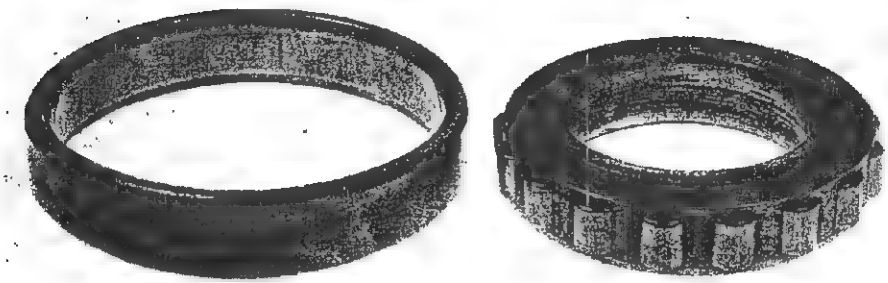
BEARING X-2 - [redacted]

25X1B



BEARING X-3 - [redacted]

25X1B

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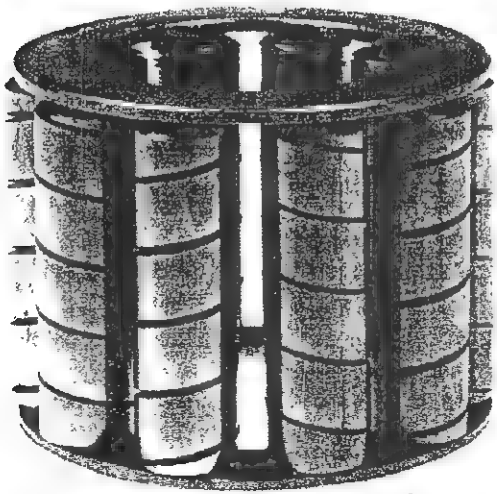
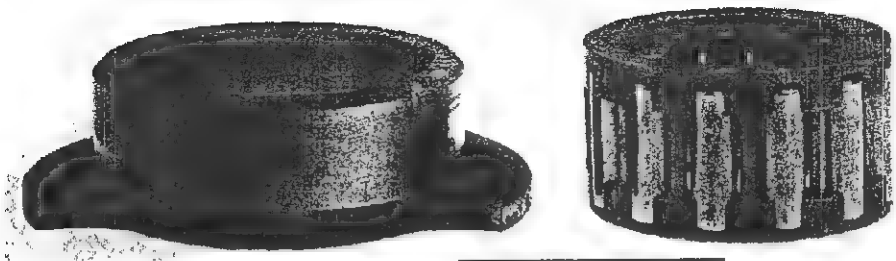


25X1B

BEARING X-4 - [redacted]



BEARING X-5 - [redacted]

25X1B

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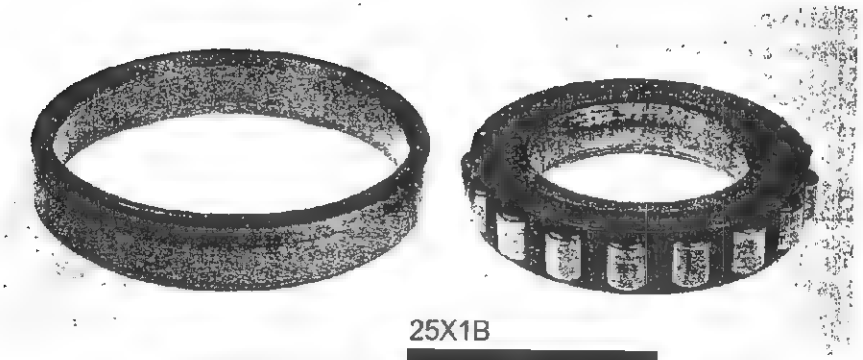
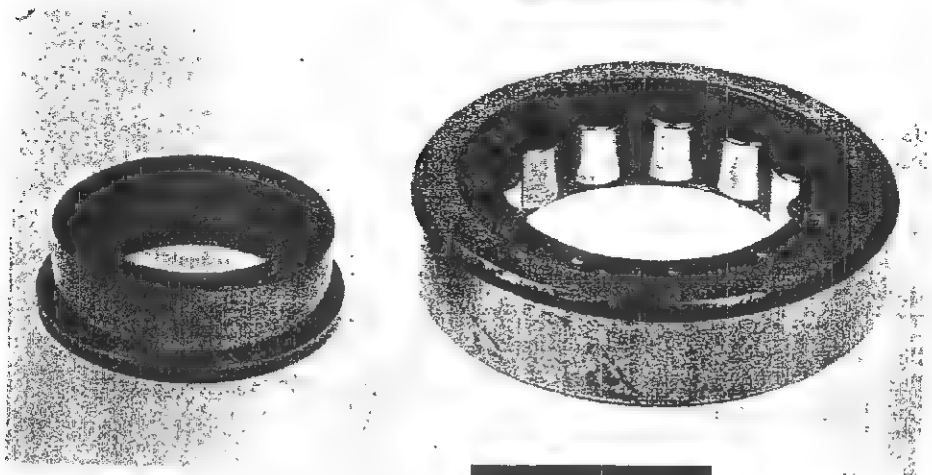


25X1B

BEARING X-6 - [redacted]



BEARING X-7 - [redacted]

25X1B

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August 7, 1951

PHYSICAL LABORATORY REPORT ON TEST NO. 369-J

Investigation of Antifriction bearings received from the Government on May 29, 1951.

A report giving an analysis of these bearings with respect to material, geometry, and finish was issued on June 29, 1951.

Object of Test:

To determine the fatigue life characteristics of one of the tapered roller bearings (Bearing No. X-2B) received with the above group.

Material Tested:

Bearing No.	Type	OD	Bore	Width
X-2B	Tapered Roller	140 mm (5.51 in)	80 mm (3.15 in)	28 mm (1.10 in)

25X1B

[redacted] this bearing has the following rating:

BRR = 3045# at 500 RPM
BTR = 2320# " " "

Method of Test:

The bearing was tested in the center position of the single unit 5" Radial-Thrust Test Machine under radial load. The cone was driven at 1785 RPM. Lubrication was spindle oil at one pint per minute. Loads were:

Radial Load Only	% Load	1 B-10	(Catalogue Rated Load For) 10% Bearing Failures
4160#	200%	300 hours	

Results of Test:

The bearing was badly spalled after running only 14 hours (0.047 B-10). See the attached Photo #4078.

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Conclusion:

Considering that the metallurgical check previously reported was good, thermal residual stresses in manufacture may be responsible for the poor fatigue life.

[redacted] bearings, tested under comparable loads, are normally inspected after 300 hours and such bad failures are seldom encountered.

25X1B

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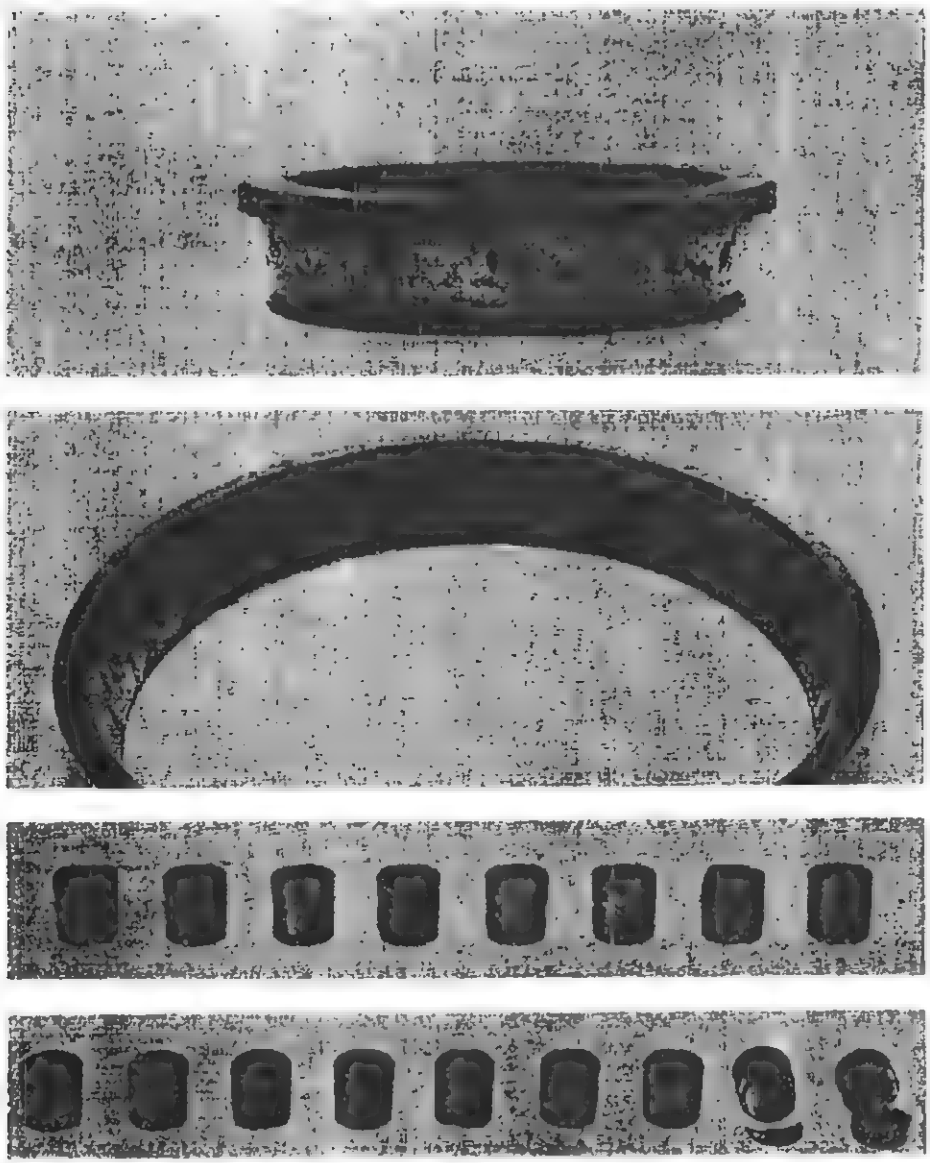

TEST NO. 369-J - #X-2B TAPERED ROLLER BEARING AFTER RUNNING 14 HOURS UNDER 200% RADIAL LOAD.

PHOTO #4078

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PRODUCTION TECHNIQUES

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25X1A

PRODUCTION APPRAISAL BY THE DODGE DIVISION

Appraisal of manufacturing methods and machinery probably used to make the G812 tank was solicited [redacted] The accompanying comment was obtained from representatives of the following departments:

Master Mechanics' Office

Tool Room

Central Pattern Shop

Foundry

Forge Shop

Editing was done only to eliminate irrelevant material and duplications and to put this information in a form appropriate for this report.

General

In the evaluation of the overall quality of machine work it was felt that most of this work had been done by unskilled labor.

Both skilled and very common labor were employed to produce this tank.

In some respects they were interested in getting it out of the factory in the shortest possible time, regardless of quality.

The workmanship on the tank itself appeared to be very crude, yet the machine work on the engine was of the type generally found in aircraft and not necessary for land vehicle engines.

The tank hull was of a welded type construction, evidently using rolled armor plate or cast slabs. These plates were more or less of regulation type and from machined surfaces showed sound metal. At various points where a torch had been used for trimming, additional labor was not put on to smooth up these areas.

Castings

While not of the same general appearance as castings used on our tanks, they would apparently serve the purpose.

In general, all castings showed solidity, although on some there were exterior marks of sand inclusions which apparently did no harm as far as their inspection was concerned.

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The castings seemed to be very well designed. They could be efficiently made without a lot of special coring or intricate molding practices.

The castings in general were very crude, but evidently were adequate for the job.

The heavy (steel) castings such as the turret and hull castings are very crude, evidently made by semi-skilled and unskilled foundry labor. The lighter (steel) castings such as track wheels, track shoes, axle brackets, etc. show much better workmanship, though in most cases would not be acceptable by American foundry standards.

The (steel) turret casting showed a very scabby condition underneath the bustle and, were it used on an American tank, would no doubt have been rejected. The riser or gate places had not been dressed up at all after being burned off with a torch.

The track shoe was cast steel, and gates had been broken off comparatively close to the casting and were not ground. The track shoes seemed to be of a well balanced design. The track wheels were of quite substantial design and seemed to be well balanced and very good looking steel castings.

Castings made of gray iron were unimportant and of small volume. With few exceptions they were very crude. They included the cylinder head covers, the water pump housing, and miscellaneous brackets and housings.

The cylinder head covers were of cast iron, very plain, and showed a condition of burned-in sand and roughness on the surface. The water pump housing was of a double outlet type to serve each bank of cylinders and was an exceptionally smooth casting.

Many aluminum sand and permanent mold castings were in evidence. Items such as the fuel injector pump housing, the oil pump housing, and the cylinder heads were made of aluminum castings.

The transmission case was made of aluminum in two halves and had been made from a sand mold with very few dry sand cores and was generally rough.

Aluminum permanent mold or die castings were also used for the engine water jacket sections. Intricate coring was done with sand cores.

Only very simple jobs were done with metal cores. Molds and dies were very crude in most cases.

The engine crankcase, the oil pan, one cylinder head, and some minor parts were aluminum sand castings.

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The engine crankcase was made of aluminum. Their molding sand showed a rather open condition, giving considerable roughness to the exterior of the casting. Generally the finishing was not as good as we would expect on castings being produced here. The block or barrel section was made of aluminum with steel liners. Some castings had been made in a sand mold, others had been made in a permanent mold with dry sand cores. In each case the cores gave a rough effect to surfaces of the casting.

The cylinder heads had been made in both permanent and sand molds. The sand mold casting was particularly rough. The port areas showed exceptional roughness from the cores, and judging from these areas one would expect to find considerable roughness and fins in the interior and jacket area of the head.

There were a number of other smaller aluminum castings, some made in full permanent molds, some in semi-permanent molds (iron molds with dry sand cores). The appearance of these castings was much the same as those described above.

No magnesium castings were noted.

Forgings

Forgings used in the subject tank were of common ordinary manufacture; no evidence of unusual technique was observed.

Forgings used on the tank proper were produced primarily with utility in mind, and had poor finish and trim. Some of the shafts and arms used as suspension parts were combinations of closed die forging and blacksmith work, with very little regard for dimensions.

A crankshaft such as that used in the G812 tank engine would require a 25,000 to 35,000 pound hammer for its mass production, using the closed die drop forge technique.

Sheet Metal

The manifolds were not cast but were made from stamped steel welded together, with heavier sections at the port flanges. The manifolds were of a very simple design, lending themselves to this type of fabrication.

Welding

The tank body was poorly welded. The weld was piled on in excessive amounts. Defects had been poorly welded and repaired.

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Surface Treatment

Some of the parts had been surface treated, including the rack gear detail in the fuel injection pump and the cylinder walls (outside - zinc plate). An item noted and regarded as unusual was what appeared to be plating on the valve springs. (These springs were zinc plated in [redacted] engine, but black oxide coated in [redacted] engine).

25X1B

Machining

25X1B

While the work in general was of a crude nature, considerable care was evidently given to some of the critical items. A high quality of machining was in evidence particularly in the fuel injector parts.

The overall machine work was poor. There seemed to be excessive machine work done on some engine parts, and a lack of machine work on other parts of the tank.

The connecting rods appeared to be well machined. Excessive polishing had been done. The cap is a self-aligning type, and this detail of workmanship appeared very good.

Profile machining in the connecting rod webbing indicated a small volume semi-mass production setup, rather than a large scale mass production.

Connecting rods and crankshafts were machined all over to a high degree of finish. Much hand polishing was in evidence.

The crankshaft was machined all over. It was felt that there was excessive work done on this part. The workmanship was fair, except for poor grinding.

The crankshaft bearing inserts looked very good from a workmanship standpoint.

The camshafts appeared to be poorly ground all over. Some crude hand finishing was attempted around the nose of the lift.

The camshaft bearing surfaces (in the aluminum pillow blocks) appeared to be poorly hand scraped. This was regarded as unsatisfactory practice.

The turret ring bearing surface was poorly machined. A turning operation was used. Shims had to be used to correct misalignment.

With the exception of a worm gear and the pair of spiral bevels, all of the gears were spur gears with indications of having been finish shaper cut, without any shaving or lapping operations. The gear tooth rounding or chamfering apparently was done by hand, using a file. This was another indication of possible low production or lack of machinery and a high rate of available manpower.

The threaded detail of the valve assembly was not too good. The adjustment of the valve depends on the thread fit, and the threads were not all alike.

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Machining Details - Transmission Case - Upper and Lower

It appears that the bottom face of the lower transmission case and the top face of the upper case were machined by a vertical lathe, such as a Bullard. These faces were machined all over because very little machining time could be saved if all the necessary bosses were to be machined separately.

Greater speed might have been obtained had a series of fly cutters been used to traverse the entire surface in one pass. However, this would have required a special machine.

After these two outer surfaces - top and bottom - were machined, the two halves of the transmission case were turned over and the mating surfaces machined, again using a vertical lathe. The nine holes for the through bolts were then drilled in each half, starting at the mating surface in each case in order to insure proper alignment at these surfaces. Possibly the bolt holes in mating flanges were also drilled from the mating surface, although these were short holes. Either a radial drill or a drill press would have been adequate for this purpose, since undoubtedly a drill jig was used. Then before the two halves were bolted together for further machining, the end of the center web opposite the entrance for the pinion assembly was faced off. This appeared to have been done on a horizontal lathe or a boring mill with a fly cutter. The two halves were then turned over and all the holes previously drilled were spot faced. Then the two halves were bolted together and a horizontal boring mill was used to bore the bearing pedestals in the three webs.

It is very likely that the three bearings in line for each of the two cross-shafts were bored simultaneously with a boring bar. A horizontal boring mill would also have served to bore the boss for the pinion assembly and to face this boss.

The two sides of the transmission case assembly were also faced off with the two halves bolted together. The facing could have been done either before or after the boring operations, probably was done before. Apparently a horizontal mill was used. Flange surfaces around the bored holes were finished by spot facing after this milling operation

The inside faces of the end bearing recesses were machined only for clearance for the gears. This machining was done apparently by horizontal milling. The faces of the bearing recesses in the center web had to be precisely flat and square, and were therefore faced either with a boring bar or a fly cutter.

Machining Details

In summary, it appears entirely possible that all machining on the two castings forming the transmission case might have been done by four

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machines: a vertical lathe, a horizontal lathe, a horizontal boring machine, and a drill press or radial drill. There is no way of knowing whether the production rate had been increased by doing several operations simultaneously. It would have been possible to face the two sides of the combined castings by simultaneous milling. Gang drilling could also have shortened production time.

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MANUFACTURING METHODS COMMENT

Study of the tank's armor brought out the following comment:

The lower sloping front plate showed likelihood of poor quench - it had cooled down too far - or of tempering at too low a temperature. However, the upper sloping front plate was found properly treated.

The evidence of grinding on the corners of the driver's hatch opening suggests lack of skill in flame cutting.

The manual welding on the hull was characterized by great roughness, suggesting low operator skill. Many cracks were found in and under the welds, some seriously weakening the joint.

Extensive riveting was used in addition to welding, to attach the final drive castings to the hull.

The turret support ring was machined after being welded to the hull, yet the turret bearing race had to be shimmed. Pieces of tinplate were used for this purpose.

Thinner armor plate was cross-rolled; thicker plate was rolled in one direction only. The rolled armor plate was judged to be (metallurgically) moderately clean to very clean, the thicker plate being the better.

The turret casting was found to be generally clean, although some inclusions were noted.

The use of the submerged arc welding process suggests knowledge of modern manufacturing techniques.

Study of the tank's propulsion and suspension parts brought out the following comment:

The gas edge-welding of the two stampings forming each manifold suggested the lack of seam welding equipment.

The crankshaft was found to be forged quite close to size.

All final drive gears and all transmission gears were forged, presumably for maximum strength as well as economical shaping.

These gears had excessively high carbon content in the thick case provided through carburizing. This promoted the brittleness and spalling that had occurred.

Maximum hardness had been reached in many of the carburized parts. For example, the oil pump idler gear was found to be 67C (Rockwell).

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Some parts we would very likely have forged were found to have been turned from large bar stock. For example, the water pump shaft had been turned from bar stock over 2-1/4" diameter in order to obtain an integral flange in another manner than forging. The valve adjusting screw lock ring used on all intake and exhaust valves on the tank's diesel engine appeared to have been turned from bar stock of more than 2" OD.

The major studs used in the engine were found to have cut threads, heat-treated after cutting. The connecting rod studs had finely ground shanks. The other studs had probably been rough ground.

Cadmium plating seemed sparingly applied where used. Plated nuts were found to have about .00014 plating thickness, or only 1/4 of that specified in American practice.

Carburizing seemed skillfully done. The screw threads of the engine valve adjusting screws were found to be neither carburized nor decarburized, though a thick case had been provided for the head.

Macro-etching of the wire used for the valve springs revealed freedom from seams and die marks, and an otherwise good surface condition. Also in connection with the valve springs, the zinc plating used apparently gave no trouble. At least none of the 192 springs examined (from the two G812 engines) was found broken.

On the other hand, the suspension springs had been wound from very crudely drawn wire. Appreciably less steel could have been used with just as great effectiveness if the deep longitudinal scratches had been avoided.

The surface finishes found on wearing parts of the engine seemed adequate for the application, though in some instances American engine parts might have been more finely finished. The following are some of the actual findings:

		Microinches
Cam face surfaces - engine camshafts	-	21 to 45
Engine valve stems - intake valves	-	19 to 20
Engine valve stems - exhaust valves	-	23 to 25
Valve adjusting screw head	-	6 to 11

The aluminum sand castings suffered from the effects of soft ramming, inferior mixes, and rough handling of cores. There were many instances of core wire and sand inclusions.

In the one instance in which chaplets were used - in the aluminum elbow in the intake air system, between the air cleaners and the intake manifolds, the resulting casting was very poor. There was severe segregation, cracking and porosity.

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The many heat-treated aluminum castings showed good technique; however, in some instances heat treatment seemed uncalled-for and rather a luxury.

Among the aluminum castings, the permanent mold castings were found in fair to poor condition in that there was much evidence of heavy parting lines and flash due to improper closing of the molds. Furthermore, the casting cleanup job was crudely done, suggesting careless or unskilled workmanship.

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WEIGHTS

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WEIGHTS OF MAJOR COMPONENTS

Weight of Hull - Stripped

Includes driver's hatch. Does not include samples cut from hull for metallurgical analysis	21,900
Samples to metallurgist	300
Total Weight of Hull	22,200

Turret - Stripped of all Parts except Gun

Does not include sample removed for metallurgical analysis, hatches, gun elevating and turret turning mechanisms	12,970
Sample to Metallurgist	70
Total	13,040
Weight of Gun and Fittings	3,210
Wt. of Turret - Completely Stripped	9,830

25X1B

Engine - [redacted] 2,005

Includes:	Does Not Include:
Oil filter and lines	Fan, flywheel, ring gear, and clutch assembly
Generator	Radiator connections
Air starter, distributor, and all lines	Stub exhaust pipes
Fuel injection pump	Intake air cleaners
Fuel transfer pump	
Intake and exhaust manifolds	
Fuel filter	
Water pump and oil pump (3 level)	
Preservative grease - amount unknown - perhaps 20 lbs.	

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WEIGHTS OF MAJOR COMPONENTS

25X1B

Engine [redacted] with fan, flywheel, ring gear, and clutch assembly and with lubricating oil 2556

Fan, flywheel, ring gear, and clutch assembly 486

Lubricating oil 80

Engine [redacted] net, as described below 1990

25X1B

Includes:	Does Not Include:
Oil filter and lines	Fan, flywheel, ring gear, and clutch assembly
Generator	Radiator connections
Air starter, distributor, and all lines	Stub exhaust pipe
Fuel injection pump	Intake air cleaners
Fuel transfer pump	
Intake and exhaust manifolds	
Fuel filter	
Water pump and oil pump (3 level)	

In the Aberdeen report the total engine weight with generator and without exhaust system was found to be 1650 lbs. In the German report this weight was shown as 1790 lbs. (811.7 Kg). In the latter report there was no indication of what was included. It is not evident why these weights reported earlier were so much lower than those of the G812 engine. However, some of the differences appear in the comparative table that follows:

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DETAIL WEIGHTS

		Corresponding Weights from German Report
Block, stripped	59	
Head, stripped	82.5	
Head cover ('48 engine)	53	
Crankcase, upper, stripped	212	
Crankcase pan, completely stripped	54	54
Crankshaft, stripped ('48)	189.5	148
Piston assembly, complete (two pistons, rings, bearings, pins, rods, nuts, etc.) ('43)	35.8	
Main clutch and flywheel assembly, complete including flange (1)	485	
Left radiator core	175	
Left radiator, complete	245	
Oil radiator, complete	47	
Right radiator, complete	243	
Generator ('48) with rubber coupling	101	80
Transmission bottom, stripped	115.5	
Transmission top, stripped	118.5	
Final drive housing, stripped	548	
Bogie wheel, stripped	546	
Suspension arm stripped (outside spring type)	231	
Suspension spring assembly, complete	128	
Track section, single, plain, with 1 pin	30	
Track section, single, lugged, with 1 pin	39	
Track drive wheel, stripped	316	

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FUEL INJECTION SYSTEM

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FUEL SYSTEM - INJECTION PUMP REPORT

25X1A

The injection pump used in the T34 tank is a copy of the German "PE 12B-100" pump with ball-type governor. The pump and component parts of the fuel injection system were examined by [redacted] engineers. Results of tests and observations made are as follows:

1 - Fuel distribution variation at full load (168 cu.mm/stroke at 900 pump rpm) was about 12% and at the low idle of 225 pump rpm was about 43%. This calibration was poor by U. S. standards and was probably below standard because of the leaky delivery valve seats and poor delivery valve gaskets.

2 - Hysteresis in the governor was small as the governor unloading and loading curves above 900 pump rpm full load speed were close. As tested on the bench, governor action and response were good, the best speed regulation realized being 12.5 - 14%.

25X1B

3 - Total full load durations were 32-34 crank degrees. Peak injection pressure at the pump was 4800 psi. It was noted that the tubing from the injection pump to the injection nozzle was of smaller internal diameter (0.067 in.) on engine [redacted] than on engine [redacted] (0.093 in.). Using the smaller diameter tubing on the same pump and nozzle resulted in a peak injection pressure of 5500 psi. No secondary injections were present in either case.

25X1B

4 - Some general observations made and differences from U. S. practices noted are as follows:

a. Camshaft lobes were symmetrical and the plunger lift was standard at 10 mm. The camshaft had five two-piece aluminum alloy bearings and two ball bearings.

b. Tappet rollers had needle bearings. General U. S. practice is to use a loose steel sleeve-type bearing between the tappet pin and the tappet roller.

c. The plungers and barrels were badly abraded, possibly because of poor fuel filtration. These abraded areas consisted of long vertical scratches on both plunger and barrel.

d. Control rack pull or force at zero rpm varied between 22 and 40 oz. (average - 32.4 oz.) with the various cam lobes at top of stroke This value is considered quite satisfactory and was possibly the result of loose plunger fits. Four of five assemblies measured 0.005.-0.006 mm plunger clearance at the helix and hydraulic sections. These figures are normal

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for a pump which has run 2500-3000 hours and do not indicate imminent failure of the pump. The fifth assembly had about 0.0025 mm plunger clearance. The loose fits were reflected in high (by U. S. standards) operating plunger leakage of 0.21% of the total pump discharge, obtained at 900 pump rpm and 4500 psi average pump peak injection pressure, using #2 fuel oil heated to 115-120°F. This leakage ultimately combines with crankcase oil and is not large enough in volume to be harmful in any way.

e. Cam lobes were scuffed and dull in appearance.

f. The upper plunger spring seat was a steel stamping contrary to U. S. practice. It was found satisfactory in operation.

g. A 1/32" diameter (approximate) hole in the nozzle holder body permitted leak-off fuel to escape into the engine lubrication oil where its effect would be negligible.

h. Governor torque control was provided by a spring loaded control rack stop at the front of the pump.

i. Longitudinal camshaft play was 0.20 mm and is the higher limit accepted in U. S. practice. Torque required to turn the camshaft with no load was 25-30 lb.in.

j. Delivery valve gaskets were of gray fibre, jacketed by copper and in rather poor condition, possibly as a result of previous repair and installation operations.

k. The governor was coupled directly to the pump camshaft. The lever ratio (rack to governor sleeve movement) was 4.2 to 1.

l. The control sleeves were designed to permit the removal of the plunger from the top of the injection pump. This is a good feature not found on all U. S. designs.

m. The injection nozzles resembled the standard German multiple hole type nozzle. There were seven 0.25 mm holes at the tip.

n. The overall quality and general appearance of the pump parts are inferior to corresponding American made parts but should be satisfactory in operation.

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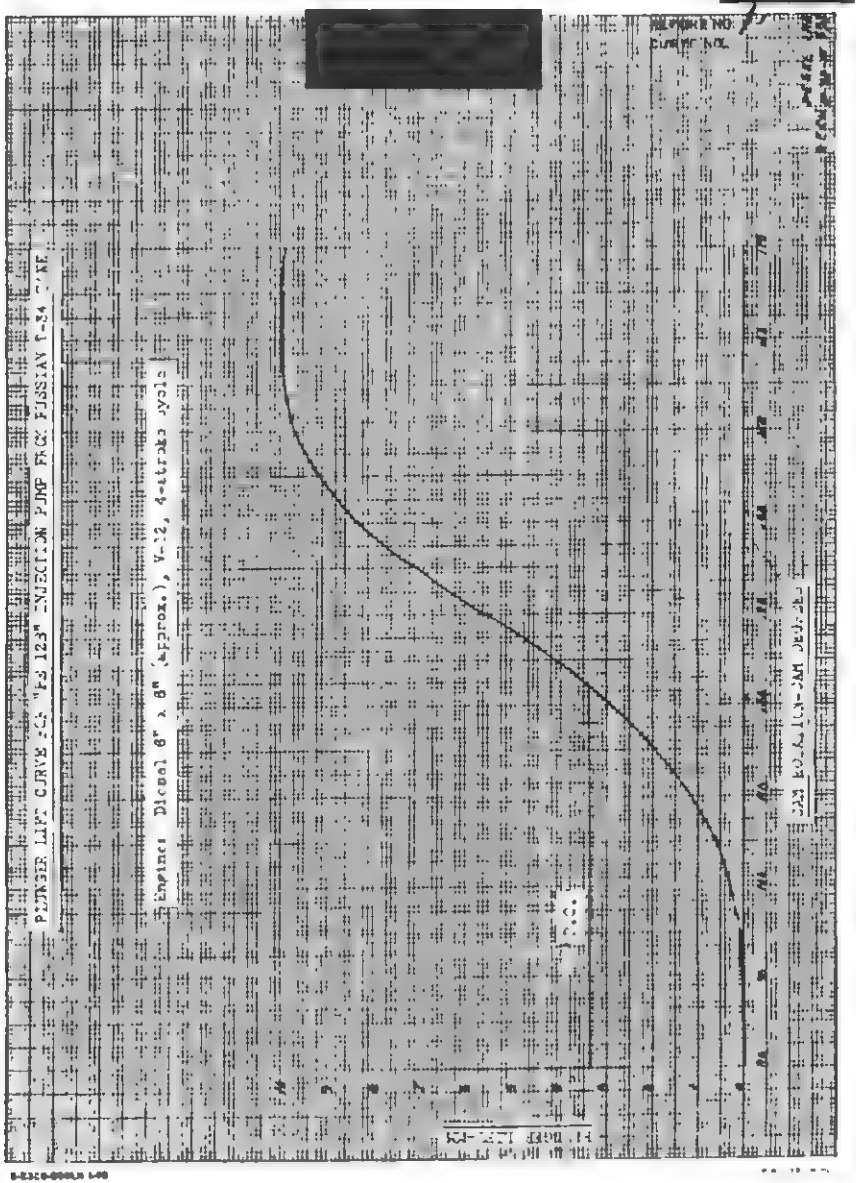

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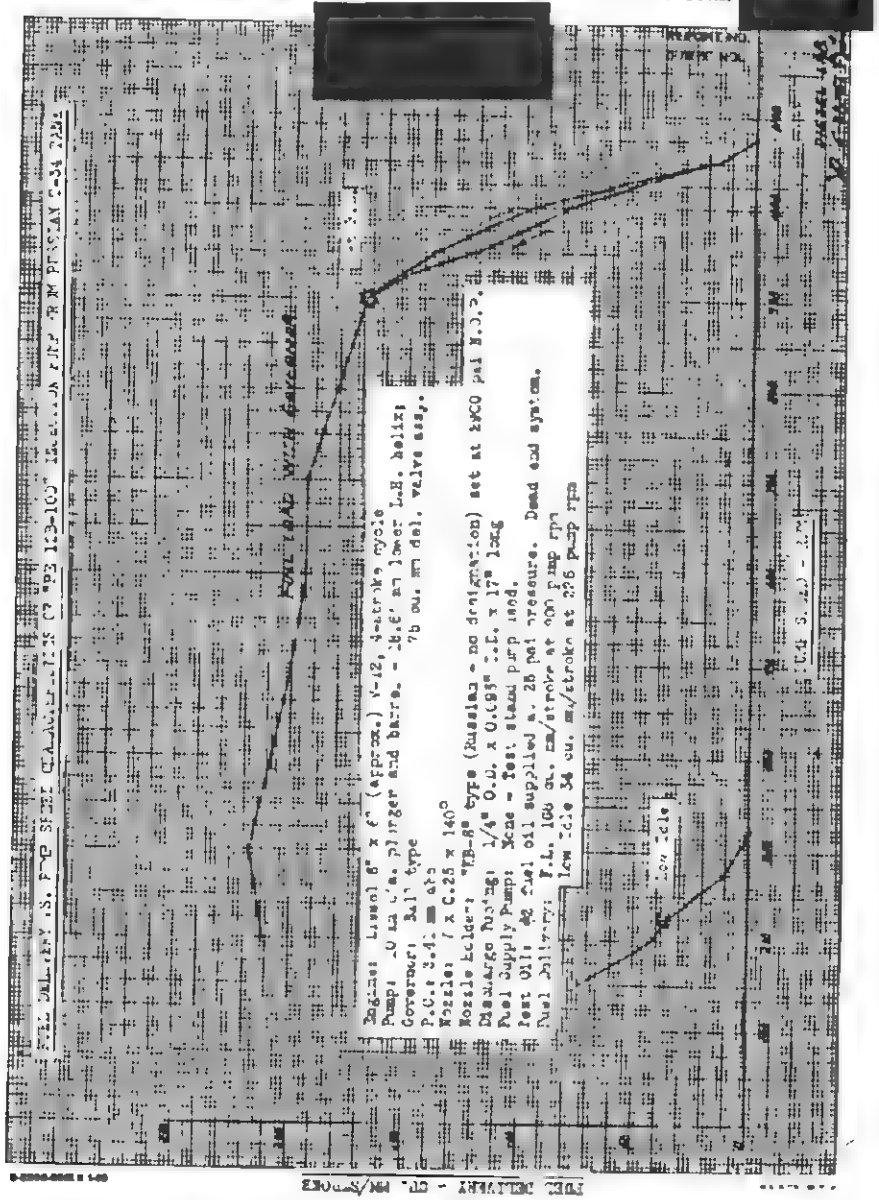

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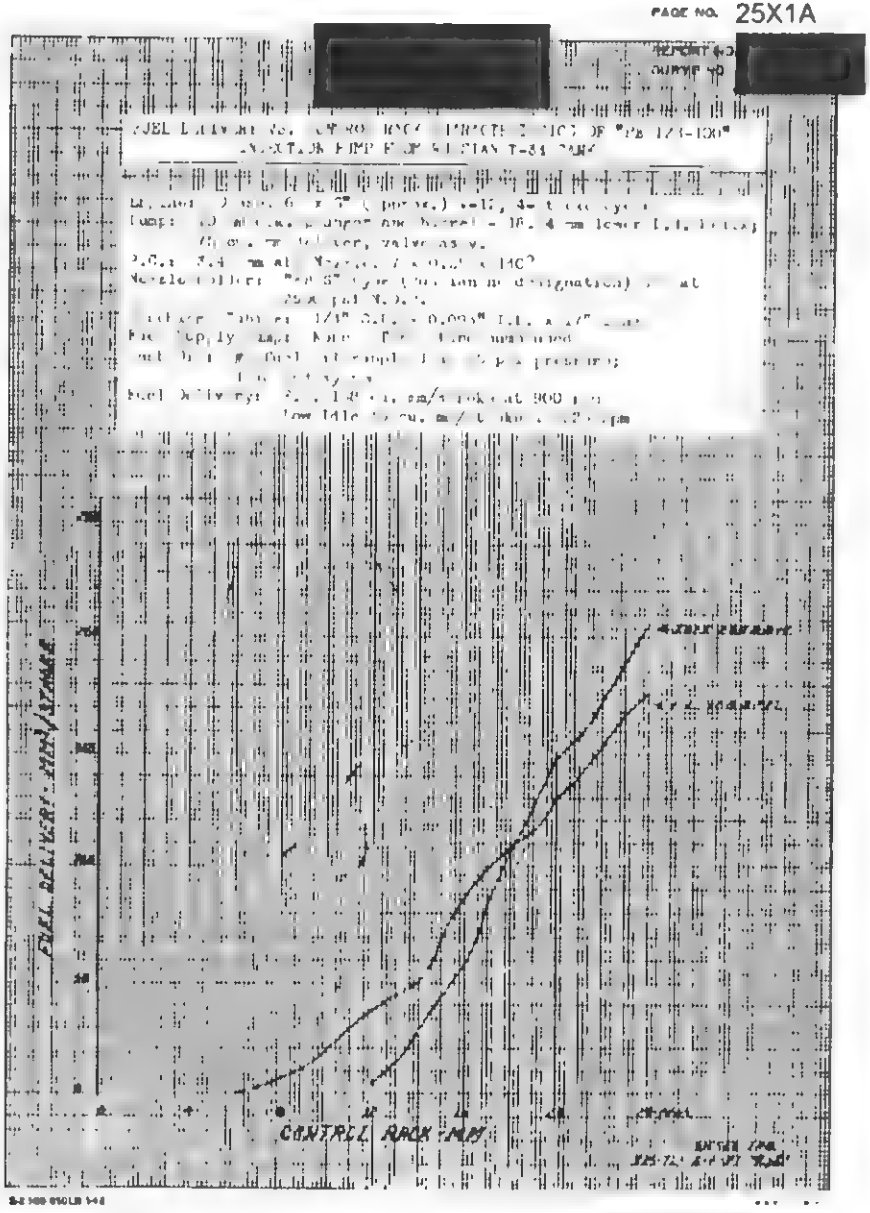

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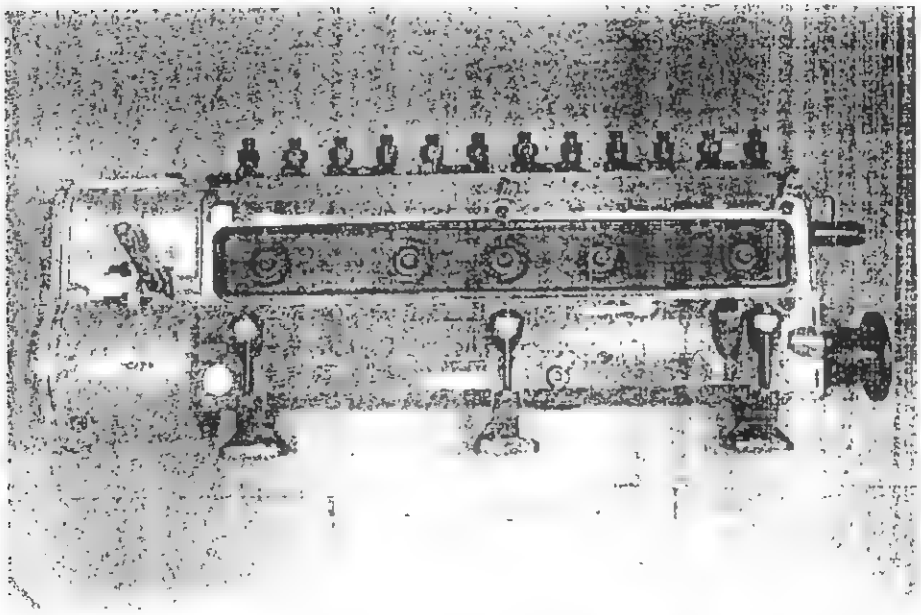

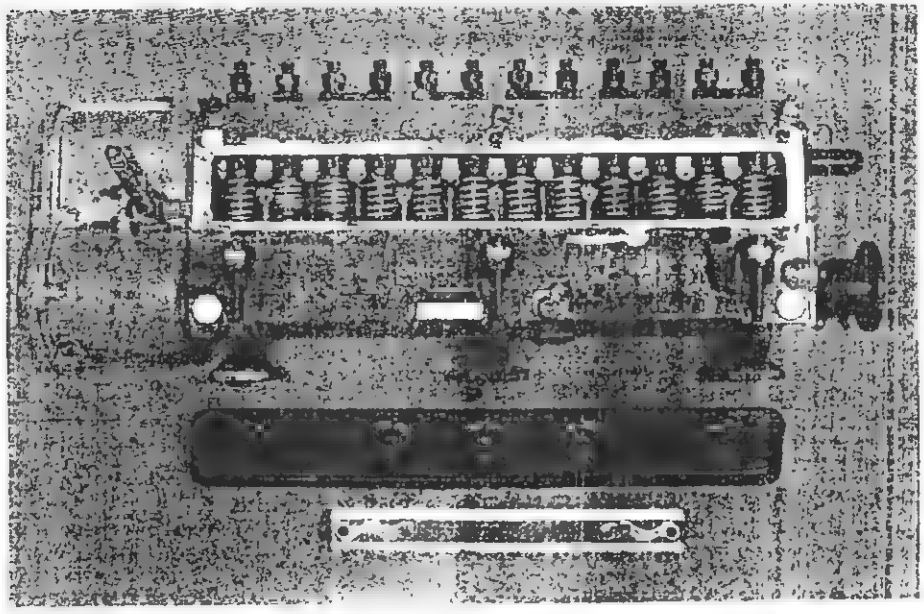

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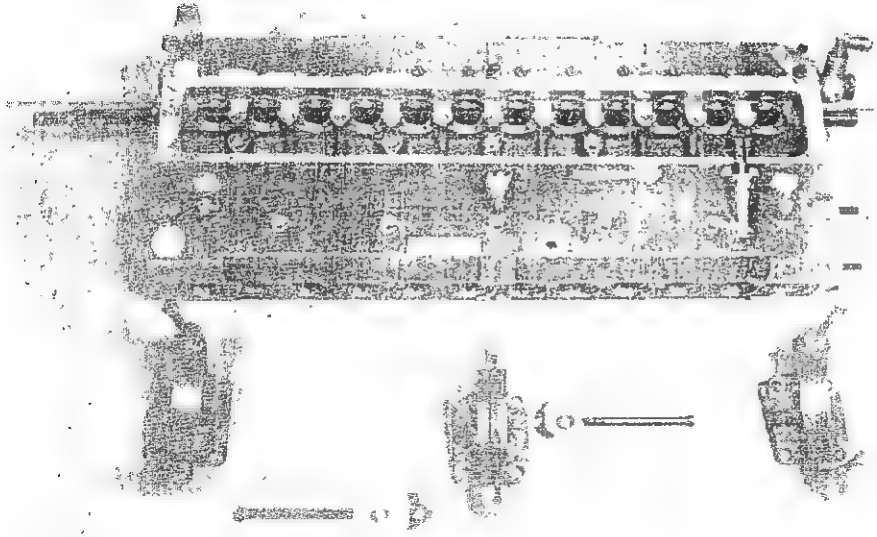

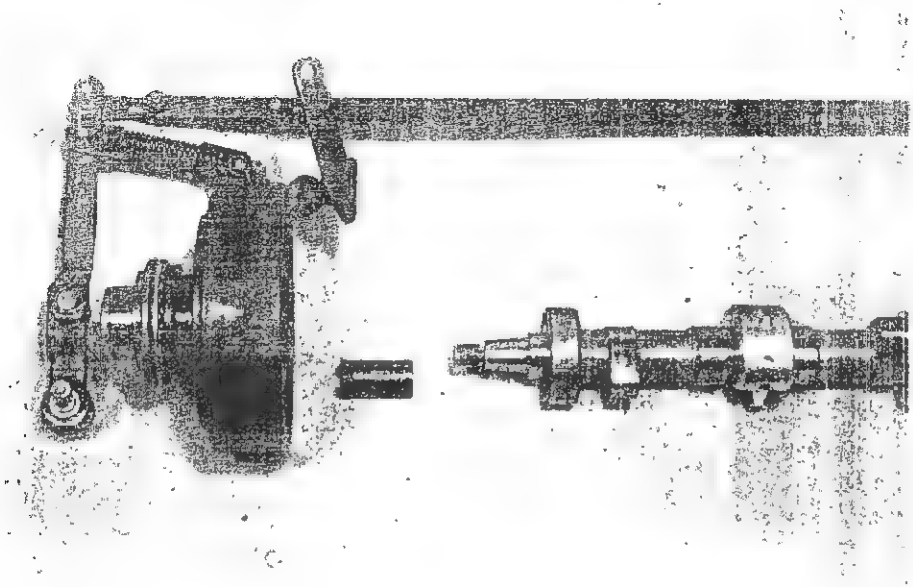

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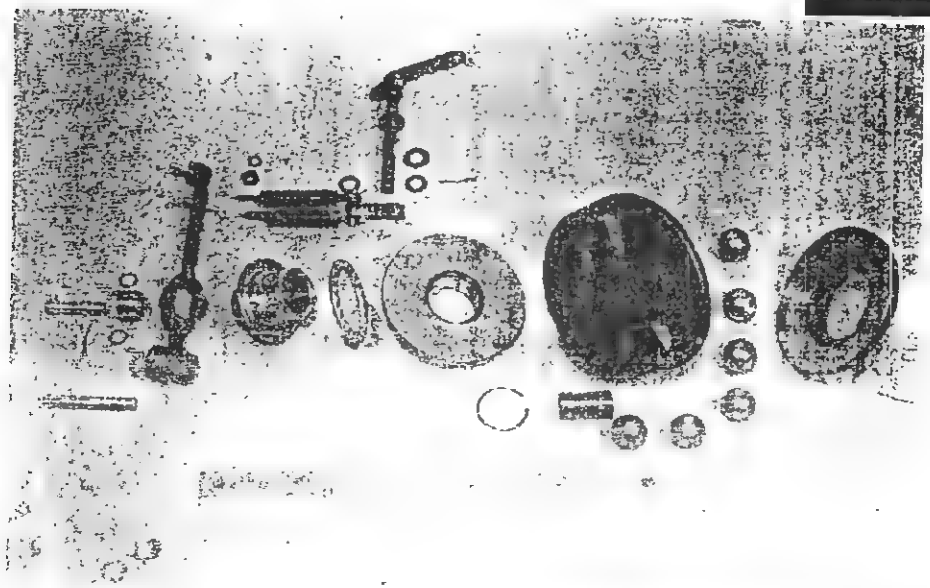

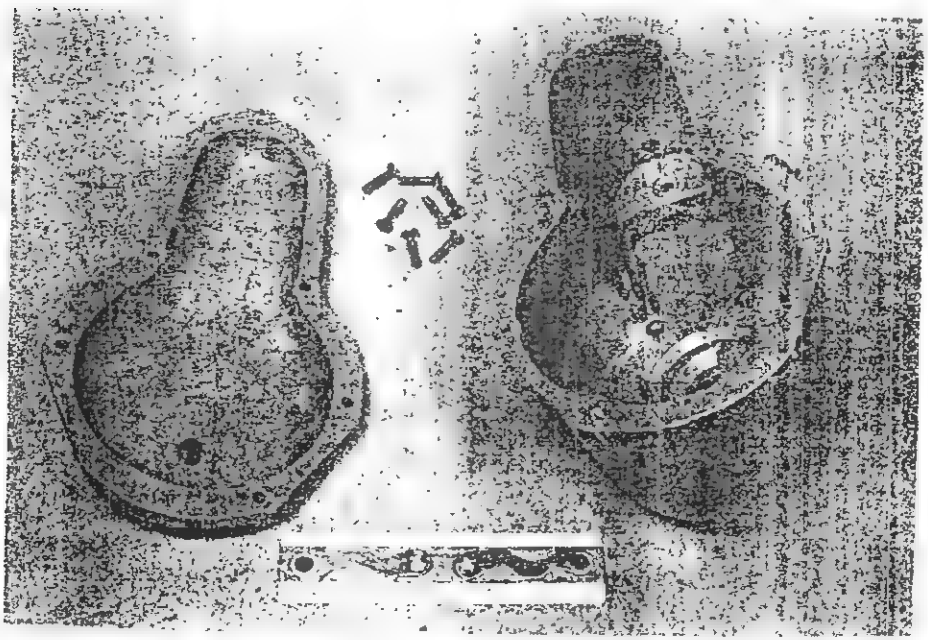

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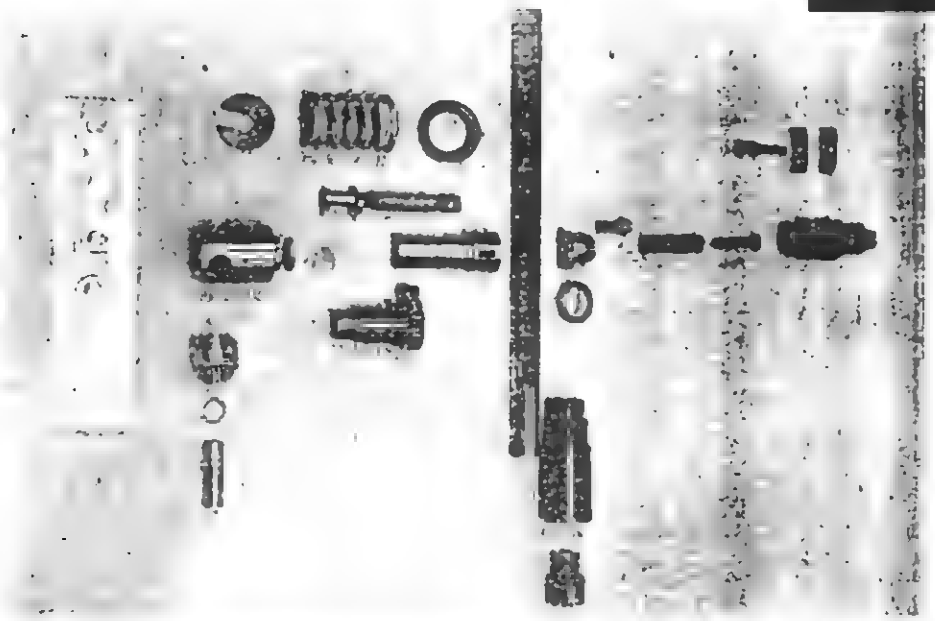

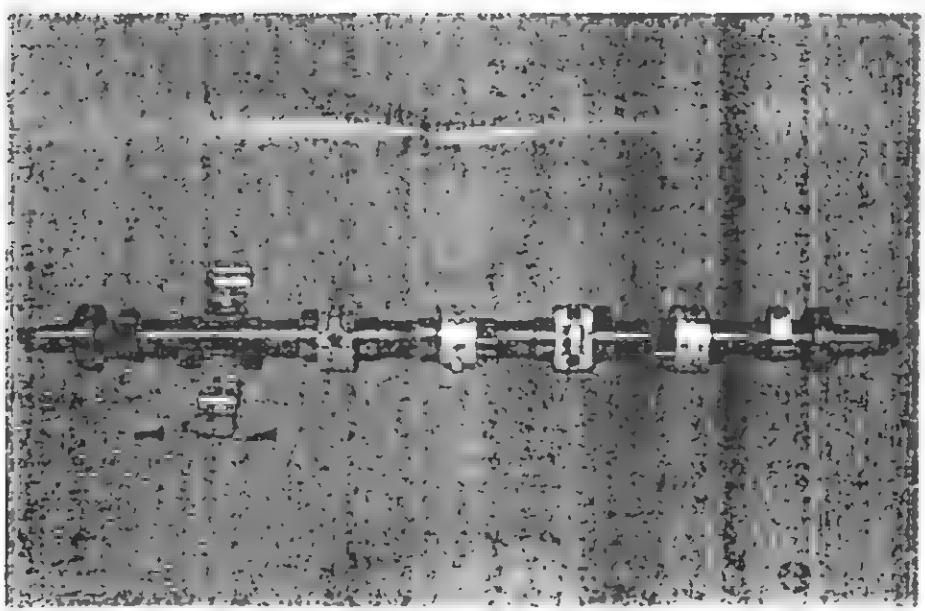

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Figure 8B

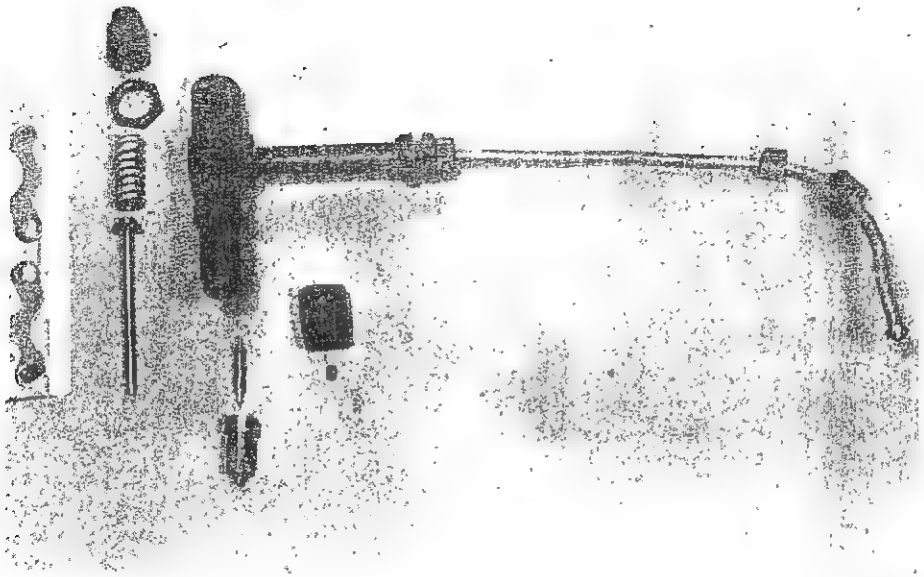

Figure 9

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ACCESSORIES - LIST

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ACCESSORY EQUIPMENT

1 - Engine Accessories

Generator
Air starter system (the electric starter also provided was located on the transmission)
Fuel injector pump, with flyball governor
Injection nozzles
Fuel transfer pump
Water pump, with pressure lubricator and with water drain valve
Lubricating oil pump
Lubricating oil filter
Fuel filter
Intake air cleaners (2)
Crankcase breather air cleaner
Tachometer drive

2 - Instruments

Engine tachometer, precision flyweight type
Speedometer - odometer - automotive type (magnetic)
Lubricating oil pressure gauge
Lubricating oil temperature gauge
Coolant water temperature gauge
Ammeter, with external zero adjustment
Voltmeter, with external zero adjustment
Azimuth indicator - 600 graduation on the ring gear and a crude pointer attached to the turret and spaced 1/2" from the graduated surface. Probable error in reading might be 1 graduation or 1 part in 600.
(No gunsight found.)
(No compass found.)

3 - Electrical Accessories

Horn - Not on tank when
Headlights - examined though
Tail light - connecting wires remained.
Interior lights
Electric starter (mounted on the transmission)
Turret traversing motor and associated gearing, and the control switch
Generator regulator - cut-out relay, voltage regulator, no current regulator
Gun firing solenoid
Four storage batteries, 12 volts, approximately 100 ampere hours
Ventilating fan
Radio aerial and wires and other evidence of radio and intercom.- equipment not actually in the tank when examined.

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4 - Miscellaneous Accessories

Air starter system - two compressed air cylinders, control valve, air distributor valve (on the engine), tubing lines, check valves at the cylinder heads - 1 valve per cylinder.
Fire extinguishers - 2 cylinders of carbon tetrachloride under gaseous pressure, with screw-type valves and no nozzles (one-half gallon each)
Miscellaneous tools, mostly very crude iron wrenches
Three externally mounted oil tanks - 25 gallons each
Five sections of track
Spare hull drain plugs, piece of tubing, towing clevis and pin, empty machine gun drum
Can for fluid - probably gasoline used to clean injector nozzles (1-1/2 gallons approximate capacity, screw cap over 1" opening)

No auxiliary power plant.

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VALVE - LIST

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LIST OF VALVES

Water Drain Valve

Located on water pump inlet, spring loaded poppet, soft seat (rubber), zinc plated steel core parts and body. Radiators have no separate drains.

Fuel Tank Selector Valve

Three-way valve, for right, left or rear group of tanks.

Radiator Pressure Control Valve

Relief both ways, two concentric poppets, all brass except spring.

Air Starter System Check Valves

Twelve spring loaded valves, to prevent combustion gases from entering air starter system.

Oil Filter Pressure Relief Valve

Spring loaded ball, to by-pass oil when filter is plugged.

Compressed Air Cylinder Valves

Flat seat, hard rubber or bakelite on brass ring seat. Valve stem operated by slotted sleeve, which is turned by outside stem. Outer end of slotted sleeve is sealed by face washer to the bottom of the packing nut counter-bore. Packing nut is sealed to valve body by another ring gasket - hard rubber or bakelite.

Air Starter Control Valve

Steel ball, self-aligning on brass conical seat integral with the valve body. Valve body appears to be lead coated, probably to seal the casting pores.

Ball Check Valve

In line from manual oil pump to engine crankshaft.

Pressure Relief Valves - in oil tank caps

Spring loaded poppet sealing on rubber ring.

Oil Pump Pressure Relief Valve

To control oil pressure.

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Twelve Sleeve Valves

Injection pump barrels and plungers

Twelve Check Valves

In fuel injector nozzles

Engine Valves

24 Intake, 24 Exhaust

Scavenge Oil Control Valve

Three-way cock valve, steel plug in lead coated brass case (coated on outside only). Directs oil to cooler or to engine pressure supply system.

Fuel System Air Bleed Valve

On-off type valve, bleeds air from fuel filter and fuel injector pump.

Fuel Tank Pressurization Pump Check Valves

Spring loaded ball-type discharge valve, poppet intake valve integral with pump piston assembly.

Fuel Tank Pressurization Control Valve

Brass tapered plug in aluminum body. To select fuel tank group for pressurizing.

Fuel Transfer Pump Relief Valve

To control fuel supply pressure. Spring loaded poppet assembly.

Pressure Relief Valve

In oil radiator end tank, to by-pass oil if radiator becomes plugged.

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CONTROLS - LIST

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CONTROLS

Steering levers - each operating a brake and a final drive clutch for one track.

Brake pedal - operating the brakes for both tracks.

Handbrake lever - a ratchet hold-down for the brake pedal.

Accelerator pedal.

Hand throttle (lever).

Transmission clutch pedal.

Transmission shift lever - with squeeze lever to be used for getting into all gears except reverse.

Starter button for electric starter.

Valve for air starter.

Fuel selector valve - to determine which set of tanks would supply fuel to the fuel transfer pump:

the left group of three,
the right group of three,
the two rear tanks.

Fuel pressurizing selector valve - to determine which set of tanks would receive air pressure from the manually operated pressurizing pump. The other two sets of tanks were then vented to atmosphere.

Pressurizing pump, hand operated, to apply air pressure to one or another of the three groups of fuel tanks.

Air bleed valve - to prevent bleeding air and vapor from the fuel filter and the fuel injection pump.

Lubricating oil pump, hand operated - to provide oil to the engine bearings just before the engine was started.

Scavenge oil control valve - to allow oil from the scavenge pumps to go to the oil cooler, or to augment the pressure pump by supplying oil directly to the oil filter inlet. In the latter case, scavenge oil pressure was then governed by the pressure relief valve in the pressure pump.

Horn button.

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Light switches - headlights,
tail light,
interior lights.

Pull control (cable) - for opening the water drain valve. Could be latched open.

Gun elevation crank - with electric gun firing trigger switch.

Gun firing pull cord - for manual firing.

Gun traversing handle - was cranked for hand traversing or swung into the plane of the cranking motion and then displaced 1/4 turn one way or the other to operate the power traversing controller switch.

Gun firing safety switch - opened by gun during recoil motion, had to be reset each time by the loader - located on the right side of the gun.

Air louver controls - 3 separate controls for the left and right louvers over the cooling air intakes and the louvers over the cooling air discharge.

Battery ground disconnect switch - to prevent battery run-down in case of a short circuit. A manual switch, however, and not a circuit breaker.

Release cables - to release whatever was held by the brackets at each side of the rear plate, on the outside of the hull.

Ventilating fan switch.

Turret lock.

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FASTENINGS

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FASTENINGS

Most screw threaded parts examined appeared to be in excellent condition, showing carefully formed threads.

Most of the larger nuts and bolts on the tank were locked by bent sheet metal tabs. This was especially true where the loosening of some one bolt could have caused serious damage. On a number of small nuts and bolts, however, split lock washers were used. There were a great many of these in sizes centering around 1/4" bolt diameter. Bolts joining the two halves of the crankcase were locked in this manner, as were the stud nuts holding down the cylinder head covers. A split lock washer was used on the end of the injection pump camshaft in order to lock a nut that had to drop into a deep recess where it would have been impractical to use wiring or sheet metal locks.

Wiring was used to hold a number of critically important bolts, especially where it was impractical to use sheet metal locks. This was true of bolts on the main clutch, for example.

The studs running from the upper crankcase through the cylinder head blocks and the cylinder heads were found very well machined, having cut threads with carefully finished bottoms and smooth fillets joining the larger threaded ends to the smaller-diameter unthreaded center section.

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FAILURES

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PART FAILURES

The following list includes those parts which were considered failed on the G812 tank:

1 - One injection nozzle pressure adjusting spring was broken on the spare engine. This appears to be a service failure, perhaps due to fatigue.

2 - One injection nozzle valve was broken on the engine removed from the tank. This also appears to be a service failure.

3 - One New Departure ball bearing in the track tension adjusting mechanism was broken. This failure probably occurred because of rough handling of the bearing during original installation.

4 - Both front suspension guide rods were bent and badly worn, due to interference between the guide rod end and the suspension lever arm when these members were at the smallest angle to each other; that is, when the corresponding bogie wheel was allowed to drop unsupported. This failure was due to an oversight in manufacturing and inspection.

5 - The transmission had by American standards already failed, although with extreme care it could have been used further. Teeth ends on all gears were battered as the result of clash shifting. Many pieces of gear teeth had been broken off and were in the transmission oil. The failure is due to inadequate design, since excellent steel was used through the transmission.

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UNEXPLAINED ITEMS

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UNEXPLAINED ITEMS

The following list includes those items that had no obvious use on the G812 tank. The items listed may have been used at one time in conjunction with parts no longer used on the T34 tank, or may have been used with parts which happened to be missing on the particular tank examined.

1 - Two of the four sets of bosses on the intake manifolds of the engine removed from the tank were not used. These apparently were formerly used to support the old hat-type air cleaner which is no longer used on this engine. The intake manifolds from the spare engine had only two sets of bosses - one set to support the fuel filter and another set which was not used. The rearmost set of bosses, used to support the water radiator filler assembly, was missing, leaving no evident means of support for the filler assembly for this engine.

2 - A welded steel hollow chamber in the lines from the oil radiator to the oil tanks served no apparent purpose other than that of an ordinary Tee connection. Vapor trap action may have been intended.

3 - A ball thrust bearing was provided at the upper end of the ventilator fan motor. This bearing was made to receive thrust only in a direction opposite to that created by the weight of the armature or the pulling effect of the fan blade. If the motor were reversed, the bearing would be used, provided the lifting effect of the fan blade was enough to counteract the weight of the armature. Even then, a special thrust bearing would not be necessary.

4 - Several brackets and bosses on the floor of the tank in the driver's compartment had no obvious use, since many of the smaller parts had been stripped from the tank before it was received. These bosses may have been provided to fasten down tools or spare parts.

5 - A smaller rectangular can (approximately 1-1/2 gallons capacity) was fastened to the floor at the right of the machine gunner. The can was empty when received but contained the odor of "sour" gasoline. This suggests that it may have contained a cleaning fluid for the injection nozzles or other engine parts.

6 - An oil port in the casting at the rear of the upper crankcase from the rear main bearing was plugged at the outer end. There was no apparent use for this port.

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DESIGN CHANGES

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DESIGN CHANGES

The following design changes were revealed upon comparison of the G812 tank, the G812 spare engine, the Aberdeen report, and the German report.

1 - Hull Exterior

The G812 tank had mounting brackets and handles not shown on the photographs in the Aberdeen report. For example, the Aberdeen tank had no brackets for spare tanks.

The rear armor plate was carried on two hinges on the G812 tank, three were found on the Aberdeen tank.

The G812 tank had a sharp edged front, while the Aberdeen tank was rounded.

On the G812 tank, the spare track sections were mounted on the front of the vehicle. On the Aberdeen tank they were on the right side.

2 - Bogie Wheels

The G812 tank had cast steel bogie wheels with solid rubber tires. The tank covered by the Aberdeen report had drawn steel wheels with perforated rubber tires. There were five bogies on a side, as shown also in the Aberdeen report photograph.

3 - Radio

The radio antenna and probably the radio were in the turret on the G812 tank - on left side next to the commander. (Aberdeen report showed it to be at lower right, in hull.)

4 - Turret Armor

Cast turret sides were 3 in. thick on the G812 compared to 2 in. mentioned in the Aberdeen report.

5 - Locking Nut Retainer - Track Idler Eccentric Support Shaft

On the G812 tank as on earlier T34 tanks examined elsewhere, the track idler eccentric was locked to the hull by a serrated flange that engaged serrations cast into the hull. These teeth were kept in engagement through tension applied to the eccentric support shaft by means of a nut located inside the tank.

In the G812 tank, this nut was prevented from loosening by means of a permanently mounted retractable spring pin that engaged splines

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on the OD of the nut, the same splines engaged by the wrench used to loosen and tighten the nut.

On the Aberdeen tank, this nut was retained by a cotter key passing through the eccentric support shaft. The Aberdeen report also indicated that, during accelerating and braking tests, one of the track adjusting eccentrics had loosened up and the idler shaft had become bent. There was no indication, however, as to whether the retaining nut or its cotter key was at fault.

The G812 design was better in any case in that there was no loose piece to be lost. The spring pin could quickly be retracted - it did not have to be driven out, or pulled out with additional tools. There was no cotter pin to break off and need replacing after several removals.

6 - Clutch Overcenter Spring

The G812 tank had an overcenter spring at the pedal for the main clutch. None was shown on the Aberdeen tank. In this manner, the force required to disengage the clutch was undoubtedly much reduced.

7 - Steering Clutch

The Aberdeen tank steering clutches each had 22 driven plates and 21 driving plates. The G812 clutches had 19 driven plates and 18 driving plates (plus two pressure plates).

8 - Instruction Plate

The G812 tank had a driver's instruction plate between the pedals for the main clutch and the brake. None was shown on the Aberdeen tank.

9 - Engine Instrument Panel

The engine instrument panel found on the G812 tank provided for the mounting of the engine tachometer on this panel, along with the water temperature and oil temperature and pressure gauges. However, the tachometer was not actually mounted in this panel. There was merely a circular opening for it. Instead the tachometer was located beside the speedometer-odometer, as had been found in the Aberdeen tank.

10 - Electrical Control Panel

On the G812 tank, four toggle switches, the horn button, a group of fuses, and the ammeter and voltmeter were all mounted on a single well-arranged panel. The Aberdeen report photographs showed these items to be somewhat scattered. On the other hand, the starter switch that had been located on the panel on the Aberdeen tank was moved away to a location very close to the air starter valve, perhaps to facilitate the simultaneous operation of the two starter systems.

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11 - Turret Traversing Mechanism - Two-Speed Control of Power Operation

The G812 tank was found to have an electric control for its turret traversing mechanism that provided two speeds in each direction. As the barrel switch providing this control was moved away from its neutral center position, it first provided connection to the motor armature through a low resistance coil. Further movement of the controlling switch away from its center position cut out this resistance coil and provided direct connection with the armature. It seemed likely that this control was provided as much for the protection of the traversing motor as for the ease of control of the turret. No indication was obtained of the relative speeds in the two positions.

The Aberdeen report mentioned "no speed regulator attachment" on the electric traversing mechanism for the turret. Later in the report the impression was recorded that there were three speeds in each direction, "all within a very close range - 10, 11 and 13 seconds." The mention of the presence of a "flexible coupling between the electric motor and the gear housing" suggested that the traversing mechanism found on the Aberdeen tank was of different design than that on the G812 tank.

12 - Generators

The generator on the spare engine was of larger overall size than the generator on the engine removed from the tank. The later generator is larger because three cooling fans have been added to it. This was done probably to help get rated output from the generator, rather than to increase overall generator capacity.

The number of armature windings and commutator segments is greater on the newer generators. This is probably to decrease radio interference.

13 - Generator Coupling

In the G812 engines, the generator was coupled to the generator drive through a rubber wafer that undoubtedly provided considerable shock absorption, as well as permitted some misalignment. The coupling mentioned in the German and Aberdeen reports was apparently a friction disc arrangement. The coupling mentioned in the Aberdeen report had failed.

14 - Engine Starter Relay

The relay shown in the Aberdeen report photographs was different in appearance from that found on the G812 tank.

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15 - Battery Disconnect Switch

A battery disconnect switch was provided on the G812 tank allowing the breaking of the connection between batteries and ground (the hull) in case of short circuit. The Aberdeen report photographs show what may have been another form of this switch in about the same location.

16 - Transmission Gear Ratios

The third speed ratio was changed since the Aberdeen report to use the same tooth combination as was used for second speed, but inverted. This resulted in fewer gear sizes to cut. No advantage of this simplification had been taken for service, however; the gears had been allowed to remain different in other details.

17 - Fuel Capacity

There were 8 tanks giving 147 gallons total capacity in the G812 tank, compared with the Aberdeen finding of 6 tanks holding 120 gallons. Additional outside drum-type tanks strapped on above the fenders had a capacity of approximately 25 gallons each, or 75 additional gallons in all. The total, including inside tanks, was 222 gallons. There was further provision for 2 additional tanks across the back. Tanks of the same diameter could be accommodated, but they would have to be about half as long as those on the sides. Two such tanks might add another 25 gallons to the capacity, for a total of 247 gallons for the G812 tank. It should be noted, however, that the outside tanks may be needed for lubricating oil rather than fuel oil.

18 - Fuel Tanks

The fuel tanks of the G812 tank, although of the same shape as those in the Aberdeen report, are made slightly differently. More extensive drawing of the sheet steel was done on the G812 tanks, resulting in less welding of seams necessary for final assembly.

19 - Air Cleaners

Two tractor-type air cleaners were used on the G812 tank, replacing the hat-type cleaner formerly used. Poor design, however, very inefficient initially due to coarse pack, and rapid loss of all filtering action (no oil bath). The centrifugal pre-cleaner, intended to remove coarse dirt, is probably worthless (as was found in other similar designs and as indicated by absence of any material in the dirt receptable at the bottom of the cleaner). These cleaners seemed wholly inadequate by any possible standard. Thus far, however, engine wear had not been excessive. This was possibly the result of running in relatively dust-free conditions (00741 Kilometers shown on odometer).

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20 - Intake Manifolds 25X1B 25X1B

Intake manifolds on engine [redacted] had only two bosses, as compared to the four found on the intake manifolds from engine [redacted] The Aberdeen report showed that the front bosses, one on each side, were used to mount the fuel filter, just as on the G812 tank. The next two pairs served to support the intake air cleaner and the final pair supported the water manifold crossing over the engine and joining the two coolant radiators. With the removal of the hat-type air cleaner, the second and third pairs of bosses were no longer necessary. The first and fourth pairs were found used on the G812 as indicated above - the fuel filter was mounted on the front pair and the water manifold on the rear pair. The second and third pairs of bosses were unused
25X1B on this tank. These two pairs of bosses could therefore be eliminated.

On engine [redacted] two pairs of bosses were eliminated, but one of these seemed to be the wrong pair. The front four bosses remained but there was no apparent provision at the rear for the support of the water manifold. Since this engine was the spare, there was no indication how these bosses were to be used.

21 - Engine Weight

The G812 engines weighed 2005 and 1970 lbs. Much of the difference between these engines could easily be accounted for in the differences in oil and grease content and in the different generator sizes.

The Aberdeen engine was reported to have weighed 1650 lbs. without exhaust system. Note that the G812 engines were also weighed without exhaust system parts, except for the exhaust manifolds themselves. The omission of even these could not be expected to explain more than 30 lbs. of the 350 lbs. difference noted.

22 - Cylinder Head Covers

These were cast iron on the G812 engines and on the engine described in the Aberdeen report. The German report mentions aluminum alloy cylinder head covers.

25X1B

Engine [redacted] had one-piece covers - there were no access plates. Engine [redacted] had covers with removable access plates. On one cover, these were cast plates and on the other these were stamped.

23 - Fuel Injection Pump Dipstick 25X1B

On the pump from engine [redacted] the one removed from the tank, the dipstick entered through the top of the injection pump and was much more easily accessible than the much shorter dipstick running through a special boss provided far down the side of the pump on engine [redacted]

25X1B

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25X1B

24 - Lower Accessory Drive Lubrication

In engine [redacted] the lower accessory drive gear and bearings were lubricated entirely by oil running and dripping down from above. In
25X1B engine [redacted] a larger oil manifold was provided, with a cast-in oil passage leading to an oil supply port running directly to the lower accessory drive. This was especially interesting in view of the fuel pump drive gear failure noted in the Aberdeen report.

25 - Oil Filter

The oil filter on the G812 engines was mounted on a cast iron bracket bolted to the upper crankcase. The German and Aberdeen tanks had an oil strainer bolted to integrally cast bosses on the lower crankcase.

26 - Oil Radiator

There was no evidence of an oil radiator on the Aberdeen tank. The German report mentioned "an oil cooler for each engine bank." The G812 tank had a fin and tube radiator, like the water radiator.

27 - Water Pump Lubrication

The German report shows a water pump seal system involving only two seals separated by a compression spring. The upper was intended to retain engine lubricating oil and the lower one to retain the water. Leakage past either of these seals was permitted to drain to the exterior of the engine. With this arrangement, a lubrication channel was provided directly to the center of the water pump bushing. There was then no lubricant storage, the excess squeezing out into the coolant water.

25X1B

On engine [redacted] three packing-type seals were found, the third being located below the other two previously reported and separated from the lower of those two by a corrugated washer trapped between two flat washers. The lubricating channel was then made to open into the space between the washers. Thus the water pump bushing was lubricated only by the lubricant that forced its way past the lowest of the seals.

Lubrication was continuously supplied, however, by the continuous pressure lubricator described in detail in this report. Had such a continuous pressure lubricator been used to supply the channel leading directly to the center of the bushing, it is likely that excessive lubricant would have found its way into the cooling system.

The G812 engines had a spring loaded constant feed assembly to supply lubricant to the water pump bushing. The German and Aberdeen tanks had only a grease fitting. The Aberdeen report showed a photograph of a badly scored impeller shaft.

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25X1B

28 - Water Pump Impeller

Engine [redacted] was found to have a permanent mold aluminum cast impeller. The Aberdeen report mentions a bronze impeller.

29 - Fuel Injection Lines

25X1B

The fuel injection system on engine [redacted] used larger internal diameter delivery lines than did the system on engine [redacted] 25X1B

30 - Crankshaft Lubrication System

In the G812 engines, lubricating oil was fed directly into the end of the crankshaft through a brass bushing which provided a running fit on the crankshaft end and a face seal on a machined surface of the oil manifold. Only oil pressure was used to force the bushing against the face of the oil manifold.

According to the German report, crankshaft oil was supplied to the front main bearing and was then fed to the crankshaft through three radial holes. The main bearing was apparently provided with a ring groove with which the three crankshaft holes registered in order to provide continuous pressure lubrication.

31 - Oil Pump Inlet Screen

The screens on the G812 oil pumps cover only the inlet ports. The screen shown in the Aberdeen photograph covered the entire head of the pump.

32 - Piston Rings

The German report showed six piston rings including one 5 mm oil scraper ring. There were only five rings on the G812 pistons, the 5 mm ring being eliminated.

33 - Cylinder Liners

The G812 engine removed from the tank had nitrided cylinder liners. A nitralloy steel was used. The liners mentioned in the German report were nitrided but a nitralloy steel was not used.

The liners in the G812 tank engines were zinc plated. The German report indicated a cadmium plate. The liners in the G812 engines were found to be about 5-1/2 mm thick but had no ribs. The German report described liners 4 mm thick provided with a number of band-type ribs.

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34 - Coolant Seal Grommets - Cylinder Head to Block

In the G812 engines, these rubber grommets were located over their corresponding coolant passages by the cylinder head gasket and were also piloted on short lengths of brass tube which extended into both the cylinder head and the block. These tubes prevented the rubber from compressing into the coolant passage and also decreased the likelihood of the breaking off of rubber particles and their being carried into the rest of the coolant system.

The German report indicated that these rubber rings were confined within metal rings 24 mm (.95 inches) OD and 6 mm high. This provided more complete confinement on the outside than was found in the G812 engine, but there was no mention of an inner confinement ring or tube.

35 - Valve Seat Inserts

The German report mentioned bronze valve seat inserts. The G812 engines had steel seats.

36 - Valve Rotation

25X1B

Engine [redacted] had the ends of the outer valve springs extended to provide locating lugs which dropped into notches in the cylinder head and in the tappet lock ring to prevent valve rotation. On engine [redacted] there were no lugs on the valve springs nor were there notches in either the cylinder head or the tappet lock rings.

25X1B

37 - Injection Nozzle

25X1B

One injection nozzle on engine [redacted] was different from the others. A screw plug in a drilled and tapped hole through the spring adjusting nut was provided, probably for access for a timing indicator. The screw plug found in this hole was not locked by any means, though the thread was straight rather than tapered.

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